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Preliminary measurement and code calculations of flow through a cascade of DCA blading at a solidity of 1.67.

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THESIS

PRELIMINARY MEASUREMENTS AND CODE
CALCULATIONS OF FLOW THROUGH A CASCADE
OF DCA BLADING AT A SOLIDITY OF 1.67

by

William D. Molloy Jr.

June 1982

Thesis Advisor: Raymond P. Shreeve

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Preliminary Measurements and Code Calculations of Flow through a Cascade of DCA Blading at a Solidity of 1.67

by

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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

An experimental program to obtain uniform inlet flow to the test blading in a large cascade facility designed to use inlet turning vanes, and to measure the conventional blade element performance, is described. Attempts to reduce non-uniformities (±1% in velocity) using screens were unsuccessful and so abandoned. Preliminary DCA blade element performance data were obtained without screens at one incidence angle before aero-mechanical problems with the inlet guide vane assembly curtailed testing. The blade surface pressure distribution at the one test condition compared very favorably with the distribution predicted using the NASA computer code QSONIC. Recommendations were made that would avoid the aero-mechanical problems encountered.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

AVDR	Axial velocity-density ratio
Cp_1	Coefficient of pressure at the inlet
Cp_2	Coefficient of pressure at the outlet
Cp_{STATIC}	Coefficient of static pressure rise
C	Blade chord (inches)
D	Diffusion factor
i	Incidence angle (degrees)
P	Pressure (in. H_2O)
Q	Dynamic pressure (in. H_2O)
T	Temperature (^oR)
X	Non dimensional velocity
β	Air angle, measured in the cascade midspan plane with respect to the axial direction (degrees)
γ	Stagger angle
σ	Solidity (C/S)
$\bar{\omega}$	Loss coefficient

Subscripts

amb	Ambient
P	Pressure
PLENUM	Plenum (supply)
s	Static
wl	North wall, lower plane

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I. INTRODUCTION

The need for lightweight, fuel efficient gas turbines that are capable of developing large amounts of thrust or power has motivated a continuing drive to obtain more accurate predictions of the flow through turbomachinery. Cascade testing of blade rows has, in the past, been a logical and relatively inexpensive way to learn more about the phenomena involved in the flow through compressor and turbine stages. It is required more today in order to verify two dimensional and near-two dimensional analysis codes for flow through cascades. Such testing also provides two-dimensional blade element performance data which, in the absence of reliable analytical predictions, are required in the design of compressors and turbine stages. Reference 1 describes how cascade measurements are obtained using a cascade wind tunnel and then used in the design process.

Before subsonic cascade wind tunnel data can be accepted as being valid, the flow conditions must meet three requirements. These criteria are discussed in detail in Refs. 1, 2 and 3. First, any disturbance in the airflow should be caused by the test blades; that is, the inlet flow to the test section must be acceptably uniform.

Secondly, the measured flow characteristics should, ideally, be independent of spanwise position along the test

blades. The flow, ideally, should be two dimensional. Duval [Ref. 3] demonstrated that excellent flow conditions could be achieved in the Naval Postgraduate School Turbo-propulsion Laboratory (NPS/TPL) Subsonic Cascade Wind Tunnel using test blades with an aspect ratio of approximately two. The absence of suction along the walls results however, in some degree of streamline contraction which is measured in terms of an Axial Velocity Density Ratio (AVDR).

The third requirement which must be satisfied is the periodicity of the inlet flow to the test section and of the outlet flow. Within one chord length of the leading edges of the test blades an upstream perturbation occurs as the streamlines adjust to negotiate the blade passages. Since the rectilinear cascade is simulating an infinite cascade of blades, the flow characteristics should be the same at corresponding axial and blade-to-blade positions within each blade passage. This same condition should be true at any measurement plane downstream of the test blading.

As described by Rose and Guttormsen [Ref. 4] several unique features were incorporated into the design of the NPS/TPL Cascade to ensure a two-dimensional and periodic flow at the test blading. Initial evaluations of the facility were conducted and reported in Refs. 3, 4, 5 and 6. Work by Moebius [Ref. 6] involved modifications to the tunnel plenum chamber which established satisfactory uniform

flow at the exit of the bellmouth contraction into the test section.

In order to maintain an aspect ratio close to 2.0 at a solidity of 1.67 Cina [Ref. 7], following the work of Duval [Ref. 3], used a cascade configuration of 20 blades with 3 inch spacing. Cina conducted a program of tests of DCA blading at five (5) different air incidence angles. With this cascade configuration, Cina found that the inlet flow to the test section was uniform in direction and of uniform static pressure, but with an imposed variation in velocity and stagnation pressure resulting from the wakes of inlet guide vanes. Although excellent periodicity was found over pairs of test blades, departure from strictly periodic conditions were detected from one blade passage to another. Cina explained this condition as being the result of the inlet guide vane wakes being separated at two inch intervals and entering a test section configured with a three inch blade spacing. Because of these flow conditions, Cina considered his results to be preliminary.

As a result of these findings the Cascade Wind Tunnel was modified so that inlet guide vanes were provided at one inch intervals. The object of the study reported herein was to obtain blade performance data on Cina's cascade with good periodic and uniform flow conditions. A necessary condition was to obtain agreement in the results for blade forces evaluated from surface pressures and from a momentum

balance. A second objective was to compare measured blade surface Mach numbers with the results of code calculations.

At the outset, it was first necessary to carry out an extensive testing program to verify the new inlet guide vane section and the effect the new spacing had on flow uniformity and periodicity. It was found that the uniformity of dynamic pressure was improved with the inlet guide vanes spaced at one inch intervals. Attempts were made to further improve the flow by the use of (various) wire screens placed downstream of the inlet guide vanes. These methods proved unsuccessful for the range of parameters tested and in fact aggravated the situation.

Cina's testing of the Double Circular Arc blading was repeated without screens and with the Cascade Wind Tunnel configured with the modified inlet guide vane arrangement. Limited measurements were obtained before aero-mechanical problems with the new IGV arrangement, at the higher tunnel speeds, were encountered.

The overall purpose of the testing program initiated by Cina was to obtain data with which to verify design optimization computer codes developed by NASA. Towards this goal a fast, reliable computer analysis code (QSONIC) for calculating the flow field about a cascade of arbitrary 2-D airfoils was obtained from NASA. The code was adapted and modified to run on the Naval Postgraduate School's IBM 370/3033 computer.

The program QSONIC was developed by NASA to overcome the Mach number limitations of the earlier program TSONIC [Ref. 8]. QSONIC is described in Ref. 9. Procedures for using the program QSONIC at the Naval Postgraduate School's computer facility are given in Appendix D. The procedures are documented for the case of the DCA blading in the NPS/TPL cascade wind tunnel. A program listing is included to document changes made to the code in order to adapt to the operating system of the NPS computer.

Preliminary results show that experimental measurements and code predictions are in very good agreement.

II. FACILITY DESCRIPTION AND MEASUREMENT APPROACH

A. SUBSONIC CASCADE WIND TUNNEL

The Naval Postgraduate School's Rectilinear Cascade Facility is shown in Fig. 1. A description of the facility as it was originally configured is given in Ref. 4. The test facility is an open cycle wind tunnel, designed for the purpose of testing cascades of axial-flow turbomachinery compressor or turbine blades. The unique design of the test section ensures that the airflow paths from the inlet guide vanes to all of the blades of the cascade test section are of equal length. This particular design was intended to eliminate the problems found in other cascade wind tunnels caused by having wall boundary layers of different thicknesses entering the cascade at different points.

As a result of the work reported in Ref. 1, two fine mesh screens were installed at the bellmouth entrance to improve flow stability. A follow-on study into the cascade performance was conducted by Bartocci and is reported in Ref. 5. As a result of Bartocci's findings, plenum turning vanes were installed to direct plenum inlet air towards the bellmouth entrance and to decrease the total pressure fluctuations present at the bellmouth entrance. Figure 2 shows the configuration of the plenum chamber as modified by Bartocci. Reference 6 describes work by Moebius that resulted

in further modification to the plenum chamber in which the original contraction was changed to two two-dimensional contractions in series. After this modification, acceptably small variations in velocity and flow angle were measured at the inlet guide vane station. Figure 3 shows the internal arrangement of the plenum chamber as modified by Moebius and as it was configured for the work presented here.

Using the plenum configuration shown in Fig. 3, Duval [Ref. 3] found that the wakes from the inlet guide vanes were not mixed out at the lower measuring plane of the test section but gave a well defined periodic variation in the impact pressure. The peak-to-peak variation was ±4% of dynamic pressure over two-inch periodic intervals. This condition was undesirable, but was tolerated while looking only to establish the values of parameters required to achieve two-dimensionality and periodicity. Since the inlet flow conditions were not uniform, mass averages were used to calculate properties at the inlet plane from probe measurements.

In order to achieve a solidity of 1.67 and aspect ratio of about 2, a blade spacing of 3 inches was required for the tests carried out by Cina [Ref. 7]. The tests showed unacceptable departures from blade-to-blade periodicity under conditions of high blade loading and the installation of additional guide vanes was recommended. The modification

to the inlet guide vane section of the tunnel resulting from Cina's findings is described in detail in Appendix A.

In the present work, several tests were completed with the tunnel further modified by the introduction of wire screens between the inlet guide vanes and the lower plane of the test section. Appendix B describes the screen material and the criteria used to select the particular screens used in this study.

B. INSTRUMENTATION

The instrumentation used in the present study is that which is described in detail in Ref. 7. Twenty static pressure taps were located on the north and south side walls. The taps on the south wall were connected to a water manometer board so that the uniformity of the static pressure distribution of the inlet and outlet could be monitored visually. Additionally, one upstream tap on each wall and one downstream tap on each wall (near the centerline) were also connected to the Scanivalve so that these static pressures were recorded.

Figure 4 shows the probe that was used for the upstream survey (at the lower plane). The probe was a United Sensor Corporation DA 125 probe, serial number A847-1, calibrated earlier at various Mach numbers and yaw angles in a calibration facility. The United Sensor Corporation DC-125-24-F-22-CD probe, serial number A981-2 (Fig. 5), which was used

at the upper plane was similarly calibrated. The characteristics of the probes were approximated analytically to facilitate automatic data reduction procedures. The calibration and application procedures were those given by Duval [Ref. 3]. Appendix B of Ref. 3 describes both the upstream and downstream probes in detail. The mounting and traversing mechanisms are described in Ref. 7.

C. REFERENCE MEASUREMENTS

Plenum chamber (supply) pressure and temperatures, and atmospheric pressure were recorded on each data scan. Plenum pressure was also displayed on a water manometer board. The total temperature in the test cascade was assumed to be the same as the plenum chamber temperature.

D. TEST BLADING

The double circular arc test blading modeled the midspan section of the stator of the compressor stage reported in Ref. 10. Coordinates describing the profile of the blading are listed in Table D-2. The leading edge and trailing edge are shown in detail in Fig. 6. A photograph of the centermost blade is shown in Fig. 7.

The three blades centrally located in the cascade were constructed with surface pressure taps along the midspan section as shown in Fig. 8. The centermost blade had 19 ports on each of the pressure and suction surfaces and one tap at the leading edge. The two blades adjacent to the

center blade had 3 surface pressure taps located on each of the pressure and suction surfaces. The surface pressure tap locations for the centermost blade are given in Fig. 9.

E. DATA ACQUISITION, REDUCTION AND ANALYSIS

Data were recorded, reduced, and plotted using the modified Hewlett Packard HP-3052A Data Acquisition System shown in Fig. 10. Reference 11 describes the system in detail. The system incorporated a HP-9845A desktop computer as a controller, with all components connected on the HP-98034A HP-IB Interface Bus. A NPS/TPL HG-78K Scanivalve Controller with two 48 port Scanivalves allowed the programmed acquisition of probe and blade surface pressure measurements.

The software used in the present study for acquisition, reduction and plotting of data were developed from software originally created by Duval and Cina. The programs are listed and described separately in Ref. 12.

The uncertainties in the measurements are listed in Table 1.

III. EXPERIMENTAL PROGRAM AND RESULTS

A. PROGRAM OF TESTS

The test program was in three phases. First, in order to verify the new inlet guide vane assembly, tests were conducted with no blading in the test section and with the upper and lower endwalls set parallel at 35° (design condition), 30° and 50° with respect to axial.

Secondly, tests were made of the effect of wire gauze screen materials in reducing non-uniformities in the flow entering the test section. Appendix B describes the type of screens used and how they were installed.

The last phase of the test program was a continuation of the work initiated by Cina. Table II lists the cascade configuration tested. One test was completed successfully before aero-mechanical problems were encountered and testing was halted until the causes were analyzed.

B. TEST PROCEDURES

1. Cascade Adjustments

In the first and second phases of testing, the same procedures were used to realign the cascade for each new configuration. The lower and upper end walls were set to the desired flow angle and the inlet guide vanes were set so that their trailing edges were approximately aligned with

the end walls. The flow was started, and the desired inlet dynamic pressure was set. All tests were run at an average dimensionless inlet velocity (X) of about .13, corresponding to an inlet flow dynamic pressure of 18 inches water. Before recording data, the water manometer board was checked to ensure that the distributions of wall static pressures at the inlet plane and outlet plane were acceptably uniform. If required, the inlet guide vanes were adjusted to obtain uniform static pressure to within ±0.5 inches of water.

In the third phase of testing, initially the procedures used by Cina [Ref. 7] were followed, namely: the lower end walls were set to the desired inlet air angle and the upper end walls were set approximately to the expected exit air angle. The inlet guide vanes were set very approximately and the cascade was turned on and set to an inlet dynamic pressure of 18 inches water. The upper end walls and the inlet guide vanes were adjusted in turn to obtain wall static pressure distributions upstream and downstream which were acceptably uniform. Using this procedure however it was found on occasion that the inlet air angle sensed by the probe at the lower plane at mid-span could be 2 or 3 degrees different from the setting of the end walls.

The following procedures was subsequently adopted. The lower end walls were set to the desired inlet air angle. The upper end walls were adjusted to be "wide open", to form a diverging passage in which, when the cascade was turned

on (to an inlet dynamic pressure of 18 inches water), the flow was completely separated. The inlet guide vanes were adjusted to obtain the required inlet air angle on the channel center line over the center 24 inches in the blade-to-blade direction. The upper end walls were then moved individually towards the vertical until the lower plane static pressure distribution was uniform and the upper plane static pressure distribution was acceptably uniform at a value close to atmospheric pressure. No readjustment of the inlet guide vanes was made.

2. Measurements

Probe surveys were carried out in the blade-to-blade direction at midspan at the upper and lower planes. In the first and second phases of testing, data were taken over approximately 24 inches of the test section at intervals of 0.25 inches. Also, in order to test the repeatability of measurements, repetitive samples were taken with the probe held fixed at midspan at the lower plane at the center, 10 inches to the right and 10 inches to the left of center.

During the third phase of testing, data were taken using the procedures established by Cina in Ref. 7.

C. VERIFICATION OF INLET GUIDE VANE (IGV) ASSEMBLY

The results of the first phase are presented (as shown in Table III) in Figs. 11 to 32. The results are arranged into groups. The first group (Figs. 11 to 14) are

measurements of tunnel conditions with the end walls set at 35 degrees. Plots of conditions at the lower plane are followed by plots of conditions at the upper plane.

Results for a wall angle of 30 degrees are given next (Fig. 15 to Fig. 18), followed by results for a wall angle of 50 degrees (Fig. 19 to Fig. 21). Data were taken over 24 inches at the lower plane, and also at the upper plane at 30°. At 50°, at the upper plane, only the center 12 inches were surveyed.

The degree of repeatability of conditions in the wind tunnel from test to test (with no change in wall setting) is demonstrated by the results plotted in Figs. 22, 23 and 24.

The last group of plots, Figs. 25 to 33, shows the degree of repeatability in the probe data from scan to scan. Data for these plots were obtained by holding the probe stationary at midspan in three specific blade-to-blade locations in turn and taking 50 repetitive scans of the channels normally recorded for survey profile data. The time interval for each scan was approximately 20 seconds.

D. TESTING WITH WIRE GAUZE SCREENS

The selection and installation of the wire gauze screens is described in Appendix B.

The measurements obtained with the various screen configurations are given (as shown in Table IV) in Figs. 34 to 45. The results are arranged in four groups.

The first group of plots (Fig. 34 to 40) give data obtained with the 16 mesh .0105 inch diameter wire screen installed. Over a blade-to-blade distance from -1.0 to 7.0 inches (Fig. 35) a peak-to-peak variation in velocity of about 1 percent was noted. This is slightly greater than the less than 1 percent (0.9 percent) variation noted over the same survey region without a screen installed (Fig. 12).

The results shown plotted in Figs. 41 and 42 were obtained with two screens installed. One screen (16 mesh, .0105 inch diameter) was installed as discussed in Appendix B, while the second screen (2 mesh, .0400 inch diameter) was attached across the duct at the leading edges of the inlet guide vanes.

The fourth group of plots (Figs. 43 to 46) show the results for two different single screens. Probe survey data for these screens was taken only at the lower plane. The results shown plotted in Figs. 43 and 44 are data obtained with a 4 mesh, .041 inch diameter wire screen installed. The variation in velocity in the blade-to-blade direction was as much as ±1.1 percent, peak-to-peak. The results shown in Figs. 45 and 46 are for a 5 mesh, .041 inch diameter wire screen. The variation in flow velocity was approximately ±1.5 percent, peak-to-peak.

E. PRELIMINARY TESTING OF DCA BLADES

The results contained in Tables V to IX and Figs. 47 to 60 are arranged in the following manner.

The results shown plotted in Figs. 47 to 60 are divided into two separate groups. The first group (Figs. 47 to 57) contain results which exhibit the quality of the wind tunnel flow conditions. The second group (Figs. 58 to 60) shows the blade forces (and surface pressures) from survey data. In the first group of figures, results are presented first to examine the inlet flow uniformity (Figs. 47 and 48); second, to examine the outlet flow periodicity (Figs. 49 to 53); and, finally, to examine outlet flow two dimensionality (Figs. 54 to 57).

All points are shown connected with straight lines.

IV. DISCUSSION OF EXPERIMENTAL RESULTS

A. EFFECT OF INLET GUIDE VANE (IGV) MODIFICATION

The probe survey data shown in Figs. 11 and 12 were taken at the lower plane, with the end walls set at 35 degrees. A turning angle of 35 degrees corresponded to the "design point" of the inlet guide vanes, when the airflow from the plenum chamber was at zero angle of incidence to the leading edge of the IGV's. These two figures show that the inlet plane total pressure at midspan in the blade-to-blade direction had a peak-to-peak periodic variation of about ±2 percent and therefore about a ±1 percent peak-to-peak variation in the velocity. Corresponding data from probe surveys at the upper plane (Figs. 13 and 14) show that periodic variations in total pressure were reduced to about 25% of the value at the lower plane by the mixing of the inlet guide vane wakes.

It can be seen in Figs. 15 to 21 that at "off-design" conditions for the IGV's (endwalls at 30° and 50°) there is a greater periodic variation in total pressure at the lower plane in the blade-to-blade direction than at the design point conditions. In Fig. 15 and Fig. 16, it can be seen that the periodic variations in total pressure are more pronounced with the flow from the plenum at a negative incidence angle to the IGV's (endwalls at 30°). Except for the first

8 data points in Fig. 15, there is a well defined period of about 1 inch of travel.

Figures 19 and 20 show the probe surveys conducted with endwalls at 50 degrees. At this off design condition the periodic variation in total pressure was considerably greater than the design point and the individual wakes from the inlet guide vanes were much less well defined.

The repeatability of the survey was examined at wall angles of both 50° and 30°. Figs. 22 to 24 show that the non-uniformities in the flow conditions were repeated to (generally) better than 0.5 percent of total pressure. The question was then, to what accuracy could the individual data points be repeated in successive samples. This was examined at several probe positions and the results given in Figs. 25 to 33 explain the departures in Figs. 22 to 24.

B. EFFECT OF WIRE GAUZE SCREENS

All testing with screens was conducted with the end walls and inlet guide vanes set to yield a flow angle of 35 degrees. The data obtained with screens installed were therefore compared with the data obtained without screens, shown in Figs. 11-14. The effect of the pressure drop across the screen on the pressure coefficient plotted in Figs. 34-35 should be noted. With the first screen installed the drop in total pressure from plenum to the probe in the lower plane was about 10 inches of water (plenum pressure minus total

pressure measured by the probe at the lower plane). Without the screen (at design conditions), the pressure drop from the plenum to the probe at the lower plane was approximately 2.0 inches of water. Since Q_{ref} was defined as the difference between plenum pressure and lower wall static pressure, the value of Q_{ref} with the first screen installed was about 28 inches water and without the screen installed, about 20 inches water. In comparing the peak-to-peak variation in P1 seen in Fig. 11 with that obtained with the first screen installed in Fig. 34, the difference in the values of Q_{ref} must be considered. Examinations showed that the peak-to-peak variation in velocity remained at approximately 1% when the screen was installed.

Figures 38 to 40 are plots of data obtained during a spanwise traverse of the probe at the lower plane. These figures show that the pressure drop through the screen and turning vanes was nearly uniform over approximately 8.0 inches of the 10.0 inch span of the tunnel.

In an attempt to generate upstream disturbances that might trigger early boundary layer transition on the IGV's and increase the rate of mixing of the wakes, a second screen was attached to the leading edge of the IGV's. The results in Figs. 41 and 42 showed that this was not the case and in fact the second screen increased the magnitude of the non-uniformities at the lower survey plane. Measurements made with a single 4 mesh (Figs. 43 and 44) and a single 5 mesh

screen (Figs. 45 and 46) of similar blockage showed that neither screen influenced the flow in a particularly favorable manner. The 4 mesh screen caused the peak-to-peak variation in velocity to be about ±1.1 percent, while the 5 mesh screen caused the variation to be about ±1.5 percent. This compared unfavorably with the variation obtained without any screen installed which was less than ±1 percent.

It was therefore decided to proceed with measurements of the test cascade without using screens.

C. PRELIMINARY TESTING OF DCA BLADES

1. Inlet Uniformity

The probe survey at the lower plane in Fig. 48 shows that the inlet plane total pressure at midspan varied in the blade to blade direction less than 0.5 inches of water, with no well-defined spatial period. This was an improvement in the inlet conditions found by Cina [Ref. 7: Fig. 16]. That the spatial period was not well defined agreed with the findings presented earlier in this report. The wall static pressure distribution (Fig. 47) showed small variations (less than 0.5 ins. water peak-to-peak at the lower plane, .4 ins. water peak-to-peak at the upper plane).

2. Two-Dimensionality

The data in Figs. 54 to 57 show that, at the downstream plane, an area of (spanwise) nearly uniform conditions

existed near the centerline of the cascade. Reference 2 points out that at higher loadings it is difficult to establish a substantial spanwise area of uniform flow in the region near the suction side of the blade. This difficulty is evident in the data shown in Figs. 54 and 55 which show that only about 20% of the spanwise distance is acceptably uniform. It is noted that Cina also found reduced areas of uniform flow at this incidence angle; however, 30-40% of the spanwise distance was found to be acceptably uniform in his case. The difference could be the result of the reduced spacing of the IGV's and its effect on the side wall boundary layers.

Figure 58 shows results for inlet and outlet flow angles and blade force vectors derived in two ways as shown in Appendix B of Ref. 7. These two methods are first the applications of momentum conservation to probe survey data and second, the integration of surface pressures measured over the blade area. Reference 2 points out that for truly two dimensional flow the blade forces derived from the two methods should be the same. As shown in Fig. 58 the magnitudes and the directions of the two vectors representing the blade forces are in reasonable agreement. It is noted however that at this particular incidence angle Cina [Ref. 7] measured blade forces that were in total agreement in direction but disagreed slightly in magnitude. The values of the

force magnitudes were about 1.5% lower than those measured by Cina.

3. Periodicity

As can be seen in Figs. 50 and 51 the total pressure and velocity qualitatively repeated fairly well over three central blade passages. Acceptably small quantitative differences are noted. There was also a small but measurable difference in the surface pressures on adjacent blades, as is evidenced in Fig. 49.

4. Blade Performance

Figures 59 and 60 are plots of the pressure and velocity distributions respectively over the centermost blade. These results compare favorably to those obtained by Cina for an incidence angle of 5.3°.

Table IX contains the blade performance parameters deduced from the probe survey data listed together with the data obtained for corresponding test parameters in Ref. 7. While differences in two sets of data are evident, the differences are not large. It is noted that the value of the loss coefficient was only 10% lower than was measured by Cina, but the AVDR was less than 2% different from unity rather than the 6.5% measured by Cina. Further measurements need to be made, particularly in the light of the following discussion, before stronger conclusions can be drawn.

5. Aero-Mechanical Problems Encountered

Fifteen cascade tests were made while evaluating the new inlet guide vane assembly and testing the wire screens. All runs were made without test blades installed, with a plenum total pressure of about 20 inches of water and with the upper and lower end walls parallel. No difficulties were encountered in establishing the desired flow conditions or in using the inlet guide vanes to arrive at a satisfactory distribution of wall static pressures.

The first time the Cascade Wind Tunnel was set up with test blades installed to take data at an air inlet angle of 39.2°, the tunnel operated normally and the test was completed. (The data from this test were subsequently found to be highly suspect and are not reported here.) During the next test, with an inlet air angle of 42.4, the start-up appeared normal and previously established procedures were used to arrive at a satisfactorily uniform wall static pressure distribution. Tunnel operation appeared to be normal while taking data, but on shutdown a very noticeable high frequency vibration was encountered. Examination of the inlet guide vanes revealed that about 40% of the 60 blades were damaged. Damage included chips missing from the trailing edges, blades bent, cracks at the weld where the blade is joined to its support and indications that the suction side near the leading edge of one blade had been vibrating

against the pressure side near the leading edge of an adjacent blade.

After the inlet guide vanes had been repaired and reinstalled extreme care was used at the beginning of the next test to adjust the inlet guide vanes, with two individuals monitoring the movement of the adjustment mechanism. (IGV adjustment mechanism is described in detail in Appendix A.) A lack of stiffness in the mechanism was suspected as having been a contributing factor to the failure.

One successful test was completed at an inlet flow angle of 42.4° and these data were discussed above.

With the next cascade configuration set, at an air inlet angle of 45.9°, when the IGV's were adjusted after starting up, high frequency vibrations were again experienced. The wind tunnel was shut down and no further testing was attempted at plenum total pressures as high as 20 inches of water gauge.

The difficulty encountered with the IGV's is not fully understood, however the lack of stiffness present in the actuation of the two separate rows of vanes is suspected of having allowed the problem to occur. Certainly, the possibility of an aerodynamic flutter condition being present (due to the misadjustment perhaps) can not be ignored. It was noticed after the initial failure that the lead screw which adjusts the IGV's could be turned but the blades mounted from only one side would be caused to rotate. This

could lead to the trailing edge of one blade contacting the trailing edge of an adjacent blade and effectively closing the blade passages.

Also, the holes in which the cylindrical shanks of the IGV's were held were found not to be uniformly machined. As much as 0.1 inches of movement at the tip of some vanes was possible while others could barely move. (The most seriously damaged blades were found in or adjacent to the larger holes.)

The tendency for the mechanism to "hang-up" on one side would be greater as the vanes became more highly loaded. It is noted that the IGV problem was encountered first when going to increased incidence angles with the compressor test cascade installed. In setting a constant plenum total pressure of 20 inches of water gauge, the static pressure increase across the test blades to a constant atmospheric pressure at the downstream side implies that a progressively increasing dynamic pressure was being generated out of the turning vanes. This can be seen in Table IX, where Q_1 for the test at $\beta_1 = 42.4$ was 25 inches of water.

V. COMPUTATIONAL PROGRAM

A. DESCRIPTION OF QSONIC

The computational code, QSONIC, was developed by the staff at the NASA Lewis Research Center.[1] This code is able to calculate the blade-to-blade flow conditions in turbomachinery blade rows assuming inviscid flow but including streamtube convergence and radius change in the throughflow direction. QSONIC is flexible enough to allow the input of the appropriate boundary conditions to calculate the flow through the test blading in the Subsonic Cascade Wind Tunnel. The program uses a fully conservative solution of the full potential equation combined with the finite volume method on a body-fitted mesh. QSONIC uses an artificial density imposed in the transonic region, if such a region exists, to ensure stability and the capture of shock waves.

The analysis used by QSONIC is a combination of transonic analysis methods to calculate the flow conditions in the vicinity of a cascade of airfoils. A conservative form of the full potential equation is discretized at every point of a body fitted periodic mesh and a mass balance is calculated through the finite volume surrounding the point. The volume

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[1]The help and advice received from Charles Farrell at NASA Lewis R.C. in the process of adapting QSONIC to the NPS computer is gratefully acknowledged.

is corrected three dimensionally for any change in streamtube thickness along a streamtube, if a quasi-3D solution is desired. Either elliptic or hyperbolic non-linear partial differential equations are used, depending on the local Mach number.

The analysis used in developing QSONIC made the following assumptions:

1) The airflow is inviscid and adiabatic.

2) The airflow relative to the test blades is steady.

3) Air is a perfect gas with constant specific heat.

4) The airflow is isentropic and any discontinuities such as shocks are so weak that they may be approximated as isentropic jumps.

5) There is no velocity component normal to the streamsurface.

6) The airflow relative to a fixed reference frame (i.e. absolute velocity) is completely irrotational.

Assumption 4 requires that the peak local relative Mach number on a blade surface be 1.4 or less. The Mach numbers measured in test blades in the Subsonic Cascade Wind Tunnel would be well within this limit. However, this limitation would probably preclude the use of QSONIC for analysis of the flow field in the NPS transonic cascade wind tunnel.

There are some combinations of blading geometry and flow conditions which cause unsatisfactory results to be generated. For example, because of assumptions 1 and 6, sharp leading edges at high incidence angles (more that a few degrees) cause large velocity peaks in the blade surface as

the flow tries to turn from the stagnation point to the suction surface.

Reference 9 gives a detailed description of QSONIC and the solution method used including the governing equations. Appendix D describes the operating procedures to use QSONIC on the Naval Postgraduate School's IBM 370/3033 computer. Appendix D also describes the input and output required as applicable to the Subsonic Cascade Wind Tunnel.

B. APPLICATION TO THE TEST CASCADE

Appendix D describes in detail the generation of the input required for QSONIC when applied to test blading in the Subsonic Cascade Wind Tunnel facility. In the present work one comparison of code calculations and measured data was made before testing was stopped. The comparison was for an inlet flow angle (β_1) of 42.4°.

Tables D.1 and D.3 show the input data generated. Table D.6 shows the flow solution output by QSONIC. The flow calculated on the blade surface, using a 15 by 97 mesh, was examined. Figure 61 is a plot of the calculated Mach number along the blade surface using two dimensional inputs. Figure 62 is a plot of computed Mach number incorporating quasi-three dimensional effects. The method of incorporating quasi-three dimensional effects is explained in Appendix D.

C. COMPARISON OF CODE CALCULATIONS AND MEASURED DATA

Table VII lists the data measured in the cascade wind tunnel. C_{p1}, C_{p2} and X_{vel} are defined in Appendix C. The surface Mach number distribution measured on the center blade is shown plotted in Fig. 63.

For comparison, the computed two dimensional, computed quasi-three dimensional, and the Mach number measured in the cascade wind tunnel are plotted together in Fig. 64.

Excellent agreement between all three cases is seen. As would be expected, the greatest difference between measured and calculated data is near the leading edge in the suction side and at the trailing edge of the blade.

VI. CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the first part of the present study, to evaluate the effects of the altered inlet guide vane spacing on flow uniformity and periodicity, the following conclusions were drawn:

1. With the inlet guide vanes operating at design, the peak-to-peak variation in velocity was about ±1%, and there was a well defined spatial period of about 1 inch.

2. Operating the cascade wind tunnel in a configuration that requires the inlet guide vanes to be set to other than zero incidence resulted in peak-to-peak variations in velocity greater than ±1% and a spatial period that was less well defined.

The second part of the study, to evaluate the use of wire gauze screens to further reduce the non-uniformities in the flow field, led to the following conclusions:

1. A 16 mesh screen with a blockage factor of .69 had a slightly aggravating effect in the variation in velocity. The peak-to-peak variation in velocity with the screen installed was slightly greater than with no screen installed. This occurred at the expense of a pressure drop of about 10" of water across the screen.

2. The use of screens with similar blockage but with larger mesh and larger diameter wires resulted in larger peak-to-peak variations in the velocity at the lower plane.

The overall objective of the present study was to measure the performance of the DCA test blading. Because of aero-mechanical problems encountered with the inlet turning vanes the performance of the blades was obtained at one

incidence angle only. The following was concluded from the limited test program:

1. As a result of the reduced inlet guide vane spacing the variations in velocity and total pressure at the inlet plane were much less than those reported by Cina.

2. Good periodicity was found from one blade passage to another.

3. An acceptable region of spanwise uniformity (20-40% of blade span) was found at the downstream plane at the one test condition reported. However, this was less than was previously reported for the same incidence angle.

4. The blade forces derived from the integration of surface pressure measurements and probe survey data were in close agreement in both magnitude and direction.

5. The Mach number measured by surface pressure taps over the surface of the blade and Mach number calculated using the program QSONIC were in excellent agreement qualitatively and reasonable agreement quantitatively.

6. The specific reasons for the aero-mechanical problems experienced with the inlet turning vanes have not been identified completely.

Based on these conclusions and other observations, the following recommendations are made:

1. Use of the present inlet guide vane assembly and adjustment mechanism for testing at inlet dynamic pressures higher than about 15 inches of water is unsafe. There are three possible solutions to this problem.

   a) Operate only within the dynamic pressure range of 10-15 inches of water.

   b) Modify the new inlet guide vane assembly so that the vanes are supported at both ends on their axes of rotation. [Supporting the IGV's from both ends would prevent flapping vibrations of the (presently) cantilevered vanes. Such vibrations, when the vanes are supported alternately from opposite ends and the gaps are small compared to the chord, might lead to a potentially destructive flutter mode at particular flow velocities.]

c) Replace the entire inlet turning vane section with one of entirely new design.

2. The procedure should be adopted immediately of adjusting the vanes and walls of the cascade at lower values of the dynamic pressure before increasing the blower speed to the desired operating condition.

3. More time needs to be spent to examine the flow field produced between the guide vanes and the test blades, and to establish the effects of the movement of the tail boards. The uniqueness of the flow field when the wall static pressure uniformity is used as a criterion of good inlet flow, needs to be examined by conducting repetitive tests at nominally similar test parameters. Only when the adjustment of the flow in the facility and the quality of the flow itself is fully understood should the measured blade performance data be accepted as final.

4. The upper electrical yaw adjustment mechanism should be replaced with a manual system to greatly decrease the time required to achieve probe pressure (angle) balancing.

5. Develop the computer code necessary to take advantage of the plotting data created by QSONIC.

6. Modify the data acquisition and reduction software for the HP 9845 so that real time plots of blade performance parameters can be displayed.

TABLE I. MEASUREMENT UNCERTAINTY

Item	Description	Method	Uncertainty
x	Blade-to-Blade dimension x = 0 in. West end x = 60 in. East end	Position Potentiometer	±.01 in.
z	Spanwise dimension z = 0 in. North wall z = 10 in. South wall	Position Potentiometer on probe mount	±.01 in.
β_1	Inlet flow yaw angle	Angle Potentiometer on probe mount (hand adjustment)	±.2 deg.
β_2	Outlet flow yaw angle	Angle Potentiometer on probe mount (motor driven adjustment)	±.5 deg.
P_{plen}	Plenum total pressure	Static tap in plenum chamber $V \simeq 0$	±.01 in. H_2O gauge
P_s	Static pressure at the test plane	Calibrated pneumatic probe	±.1 in. H_2O gauge
$P_{w\ell}$	Static pressure at x = 0 in., y = -16.25 in., z = 0 in.	Static tap on North wall	±.01 in. H_2O gauge
P_{ATM}	Atmospheric pressure	Absolute Strain Gauge Transducer	±.3 in. H_2O
P	Pressure	Scanivalve Transducer	±.01 in. H_2O gauge

TABLE II. CASCADE CONFIGURATION FOR DCA BLADE TESTS

Constant Parameters

Number of Blades	20
Spacing (Pitch)	3 inches
Chord	5.01 inches
Solidity	1.67
Thickness	7.0 percent of chord
Camber Angle	45.72 degrees
Stagger Angle	14.72 degrees

Variable Parameters

β_1	42.4 degrees
i	5.3 degrees

TABLE III. SUMMARY OF MEASUREMENTS WITHOUT SCREENS

β_1	Survey Plane	Survey Direction	Fig. Nos.	Purpose
35	Lower	B-B (24 inches)	11 & 12	Flow Field Determination
	Upper	B-B (24 inches)	13 & 14	
30	Lower	B-B (24 inches)	15 & 16	
	Upper	B-B (24 inches)	17 & 18	
50	Lower	B-B (24 inches)	19 & 20	
	Upper	B-B (12 inches)	21	
50	Lower	B-B (24 inches)	22 & 23	Survey Repeatability
30	Lower	B-B (24 inches)	24	
30	Lower	Fixed Probe (10" L. of ℄)	25-27	Point Repeatability
		(on ℄)	28-30	
		(10" R. of ℄)	31-33	

TABLE IV. SUMMARY OF MEASUREMENTS WITH SCREENS
$(\beta_1 = 35^{\circ})$

	Screen	Survey Plane	Survey Direction	Fig. Nos.
1.	16 mesh .0105 wire	Lower	B-B	34 & 35
		Upper	B-B	36 & 37
		Upper	Spanwise	38-40
2.	16 mesh .0105 wire + 2 mesh ahead of IGV's	Lower	B-B	41 & 42
3.	4 mesh .041 wire	Lower	B-B	43 & 44
4.	5 mesh .041 wire	Lower	B-B	45 & 46

TABLE V. PROBE DATA, UPPER PLANE AT MIDSPAN (i = 5.3°)

DATA FROM FILE UBRED2:T14
BLADE TO BLADE TRAVERSE MIDSPAN

UPPER PLANE

Point	Loc(in)	Beta	Q/Q1bar	Ps/Q1bar	Pt/Q1bar	X/Xbar
1	-7.31	-1.59	.5686	.2614	.0920	.6475
2	-6.84	-.84	.5532	.2669	.1041	.6381
3	-6.37	-.83	.4276	.2561	.2396	.5630
4	-5.87	-2.56	.5096	.2707	.1380	.6149
5	-5.67	-2.56	.5622	.2638	.0995	.6428
6	-5.48	-2.56	.5780	.2534	.0902	.6530
7	-5.23	-1.79	.5739	.2573	.0916	.6503
8	-5.04	-1.79	.5747	.2626	.0927	.6483
9	-4.80	-1.78	.5697	.2578	.0952	.6480
10	-4.60	-1.78	.5705	.2588	.0901	.6495
11	-4.41	-1.78	.5687	.2575	.0955	.6478
12	-4.16	-1.36	.5650	.2591	.0994	.6451
13	-3.96	-1.35	.5629	.2606	.0987	.6443
14	-3.78	-1.36	.5462	.2682	.1123	.6333
15	-3.58	-1.36	.4863	.2684	.1739	.5978
16	-3.39	-1.35	.4349	.2611	.2269	.5677
17	-3.19	-1.88	.4239	.2571	.2456	.5597
18	-3.00	-3.16	.4886	.2738	.1668	.5989
19	-2.80	-2.41	.5467	.2744	.1108	.6318
20	-2.60	-2.19	.5717	.2636	.0962	.6461
21	-2.40	-1.92	.5751	.2608	.0951	.6482
22	-2.20	-1.92	.5773	.2597	.0926	.6498
23	-2.01	-1.92	.5814	.2599	.0926	.6507
24	-1.81	-1.92	.5810	.2612	.0951	.6493
25	-1.61	-1.48	.5765	.2606	.0901	.6502
26	-1.42	-1.47	.5755	.2644	.0912	.6483
27	-1.22	-1.48	.5748	.2626	.0947	.6476
28	-1.02	-1.46	.5679	.2661	.1004	.6430
29	-.83	-1.47	.5378	.2726	.1217	.6267
30	-.64	-1.46	.4704	.2693	.1954	.5862
31	-.44	-1.47	.4140	.2553	.2698	.5497
32	-.25	-1.47	.4295	.2658	.2442	.5594
33	-.05	-3.00	.5011	.2740	.1616	.6040
34	.15	-2.32	.5562	.2718	.1040	.6371
35	.36	-1.74	.5776	.2672	.0879	.6488
36	.55	-1.71	.5795	.2636	.0865	.6509
37	.75	-1.83	.5880	.2591	.0872	.6541
38	.95	-1.83	.5915	.2613	.0833	.6554
39	1.15	-1.83	.5902	.2591	.0844	.6555
40	1.35	-1.83	.5903	.2587	.0833	.6561
41	1.85	-1.83	.5810	.2601	.0922	.6506
42	2.35	-1.83	.4490	.2598	.2202	.5749
43	2.85	-1.84	.4421	.2670	.2278	.5681
44	3.34	-2.01	.5722	.2600	.0990	.6465
45	3.85	-2.01	.5763	.2597	.0972	.6481

TABLE VI. PROBE DATA, LOWER PLANE AT MIDSPAN (i = 5.3°)

DATA FROM FILE LBRED2:T14
BLADE TO BLADE TRAVERSE MIDSPAN

LOWER PLANE

Point	Loc(in)	Beta	Q/Q1bar	Ps/Q1bar	Pt/Q1bar	X/Xbar
1	-4.00	-42.43	.9533	-.1372	.0932	.8457
2	-3.50	-42.42	.9603	-.1444	.0967	.8474
3	-3.00	-42.42	.9567	-.1427	.0996	.8454
4	-2.50	-42.44	.9614	-.1519	.1031	.8480
5	-2.00	-42.43	.9741	-.1469	.0871	.8524
6	-1.50	-42.43	.9767	-.1493	.0875	.8532
7	-1.00	-42.43	.9722	-.1481	.0889	.8522
8	-.50	-42.43	.9743	-.1564	.0921	.8546
9	0.00	-42.43	.9799	-.1567	.0935	.8540
10	.50	-42.42	.9849	-.1592	.0854	.8585
11	1.00	-42.43	.9814	-.1604	.0850	.8593
12	1.50	-42.43	.9871	-.1628	.0779	.8635
13	2.00	-42.43	.9787	-.1615	.0890	.8582
14	2.50	-42.43	.9742	-.1632	.0971	.8556
15	3.00	-42.41	.9731	-.1650	.1059	.8526
16	3.50	-42.42	.9807	-.1663	.0924	.8589
17	4.00	-42.44	.9736	-.1651	.0968	.8567

TABLE VII. CENTER BLADE DATE (i = 5.3°)

X/C	Y/C	Cp1	Cp2	Mach	Nvel
PRESSURE SIDE CENTER BLADE					
.0007	.0054	.6655	.4573	.1785	.0796
.0160	.0019	.6417	.4140	.1849	.0824
.0319	.0066	.5240	.1999	.2136	.0951
.0479	.0112	.5287	.2083	.2126	.0946
.0858	.0215	.4871	.1327	.2219	.0988
.1218	.0303	.4818	.1230	.2231	.0993
.1956	.0452	.4700	.1017	.2257	.1004
.2695	.0576	.4757	.1120	.2244	.0999
.3433	.0663	.4764	.1133	.2243	.0998
.4192	.0716	.4892	.1366	.2215	.0986
.4930	.0736	.4871	.1327	.2219	.0988
.5669	.0727	.4771	.1146	.2241	.0997
.6407	.0678	.4956	.1482	.2201	.0979
.7146	.0601	.4889	.1359	.2216	.0986
.7884	.0487	.4949	.1469	.2202	.0980
.8283	.0411	.4672	.0965	.2263	.1007
.8683	.0327	.4537	.0719	.2292	.1020
.9082	.0230	.4245	.0189	.2354	.1047
.9481	.0123	.3815	-.0594	.2443	.1086
.9880	.0006	.2778	-.2482	.2646	.1175
SUCTION SIDE CENTER BLADE					
.0160	.0227	-1.3641	-3.2355	.4973	.2171
.0319	.0310	-.7756	-2.1647	.4249	.1867
.0479	.0389	-.4980	-1.6597	.3878	.1709
.0858	.0563	-.3541	-1.3979	.3675	.1622
.1218	.0710	-.3431	-1.3778	.3659	.1615
.1956	.0970	-.2923	-1.2853	.3585	.1583
.2695	.1170	-.2500	-1.2084	.3522	.1556
.3433	.1309	-.2038	-1.1243	.3453	.1526
.4192	.1399	-.1540	-1.0338	.3377	.1493
.4930	.1432	-.0854	-.9090	.3270	.1447
.5669	.1412	-.0584	-.8599	.3227	.1428
.6407	.1339	.0102	-.7351	.3116	.1380
.7146	.1209	.0631	-.6387	.3028	.1342
.7884	.1021	.1456	-.4887	.2886	.1280
.8283	.0895	.1911	-.4059	.2805	.1245
.8683	.0755	.2326	-.3303	.2730	.1212
.9082	.0593	.2636	-.2740	.2673	.1187
.9481	.0407	.2842	-.2365	.2634	.1170
.9880	.0206	.2948	-.2171	.2613	.1161

TABLE VIII. ADJACENT BLADES DATA (i = 5.3°)

X/C	Y/C	Cp1	Cp2	Mach	Avel
PRESSURE SIDE LEFT BLADE					
.1218	.0303	.4014	-.0231	.2402	.1068
.4192	.0716	.4619	.0868	.2275	.1012
.8283	.0411	.4491	.0835	.2302	.1024
SUCTION SIDE LEFT BLADE					
.1218	.0710	-.3438	-1.3791	.3660	.1615
.4192	.1400	-.1505	-1.0273	.3371	.1491
.8283	.0895	.1975	-.3943	.2794	.1240
PRESSURE SIDE RIGHT BLADE					
.1218	.0303	.4640	.0907	.2270	.1010
.4192	.0716	.4658	.0939	.2266	.1008
.8283	.0411	.4597	.0829	.2279	.1014
SUCTION SIDE RIGHT BLADE					
.1218	.0710	-.3285	-1.3513	.3638	.1606
.4192	.1400	-.1519	-1.0299	.3374	.1492
.8283	.0895	.1911	-.4059	.2805	.1245

TABLE IX. BLADE PERFORMANCE DATA

	Present Results	From Ref. 7
β_1	42.42	42.42
i	5.3	5.3
β_2	1.85	0.4
δ	10.44	9.0
D	0.455	0.46
$\bar{\omega}$	0.037	0.041
$\dfrac{\omega \cos^3 \beta_2}{2 \sigma \cos^2 \beta_1}$	0.020	0.023
$\dfrac{\omega \cos \beta_2}{2\sigma}$ $(\times 10^2)$	1.09	1.242
AVDR	1.015	1.065
$C_{P_{STATIC}}$	0.413	0.351
C_{xM}	-1.385	-1.380
C_{yM}	-0.669	-0.566
C_{xB}	-1.330	-1.476
C_{yB}	-0.572	-0.645
$\bar{Q}_1$ (in. H_2O)	25	22
$\bar{X}$	.14	.12

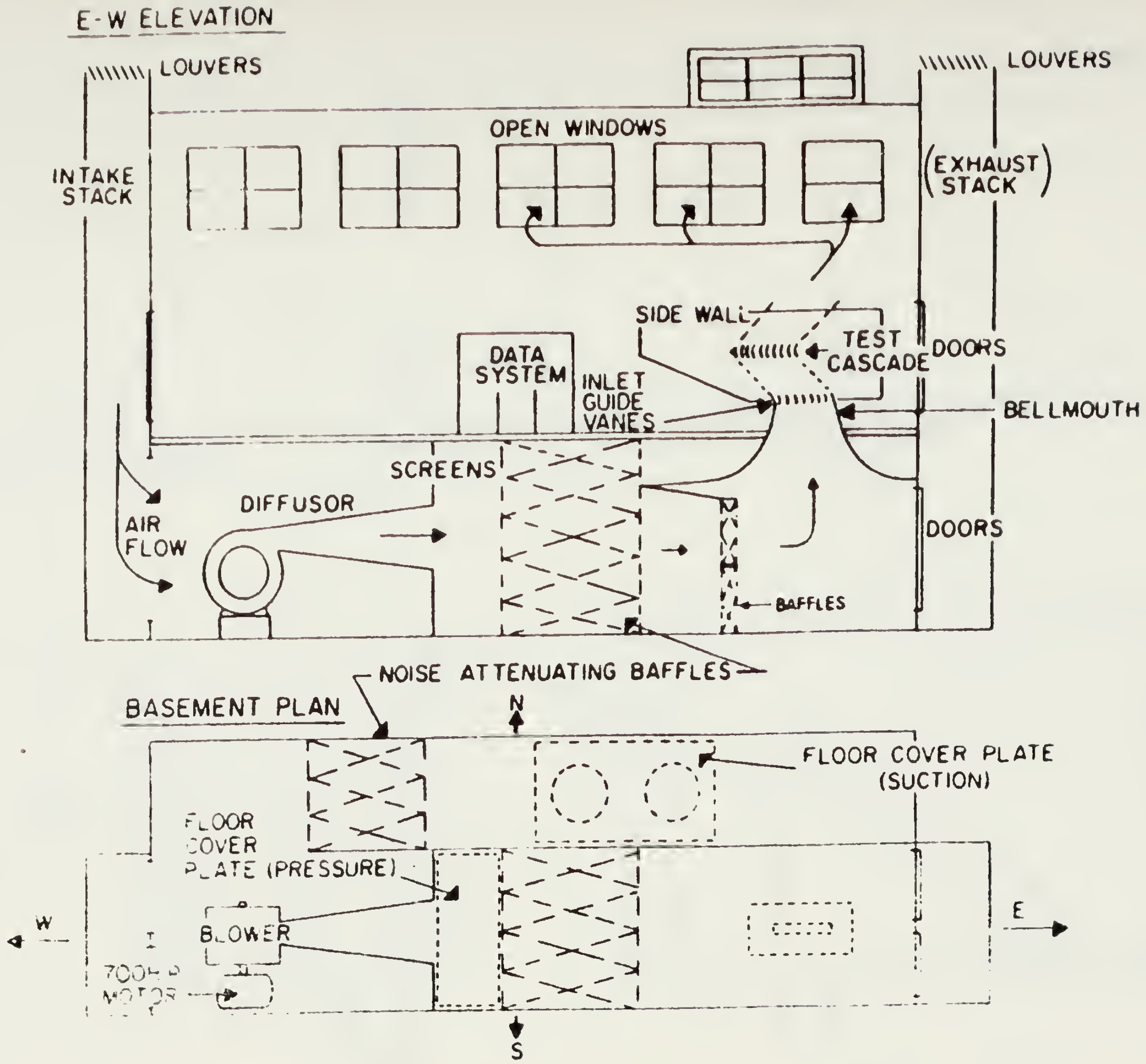


Fig. 1. Subsonic Cascade Facility

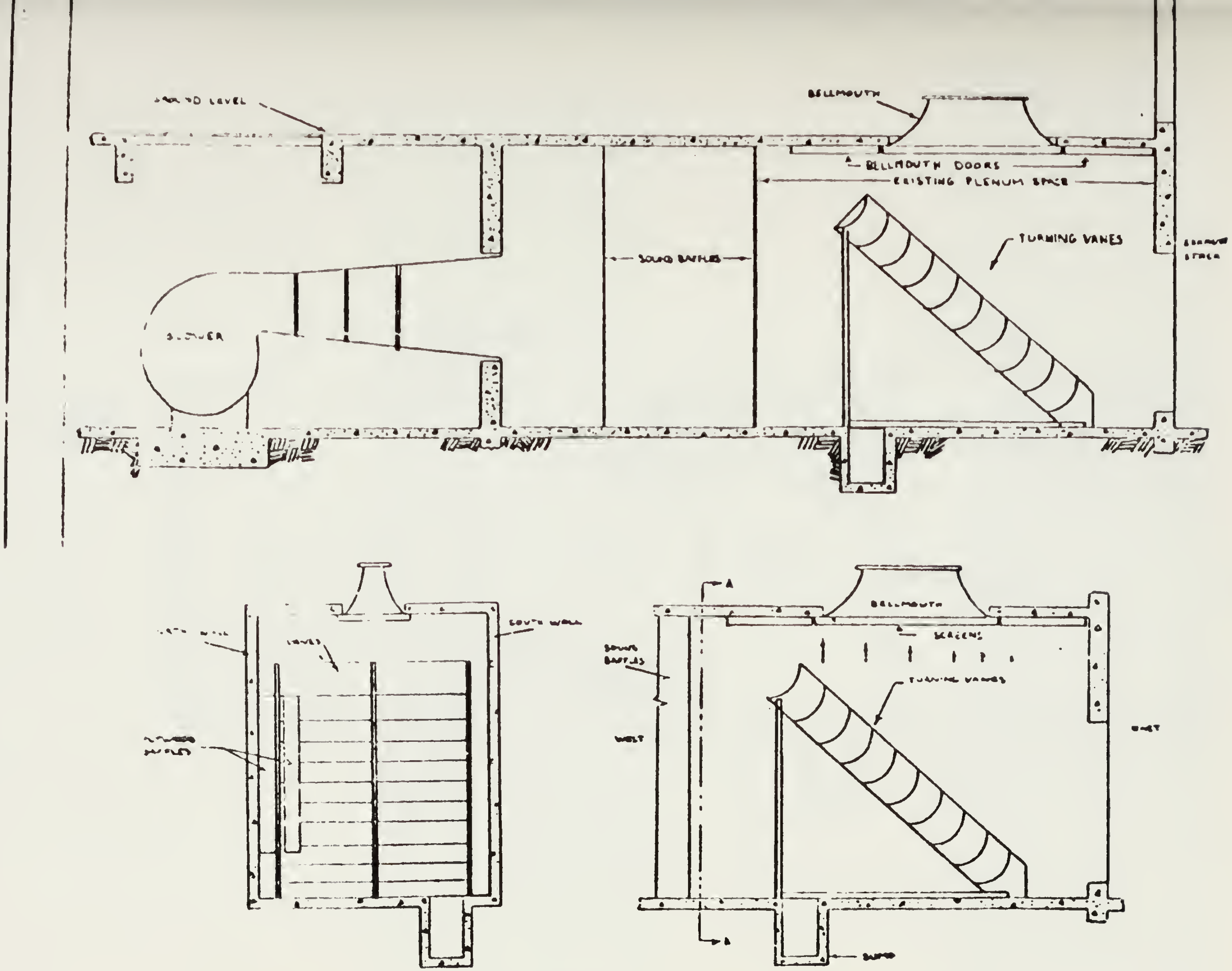


Fig. 2. Plenum Chamber as Modified by Bartocci

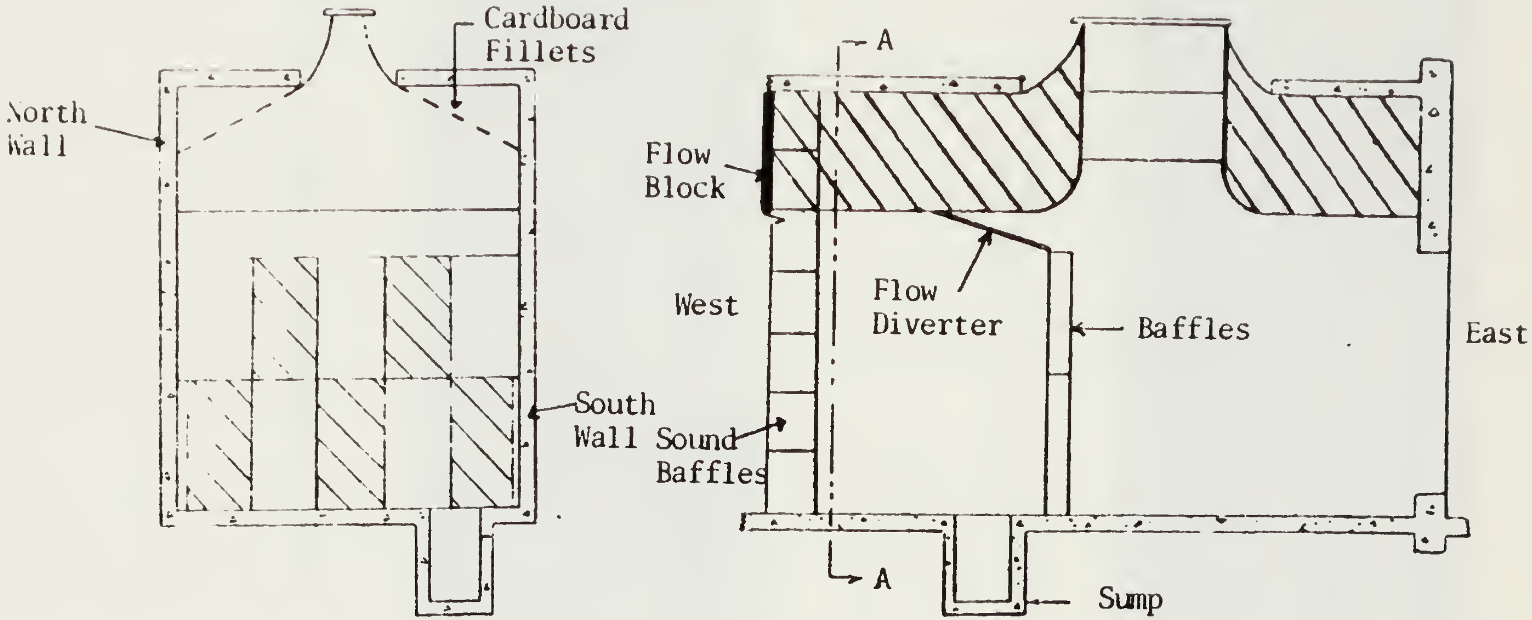


Fig. 3. Plenum Chamber as Modified by Moebius

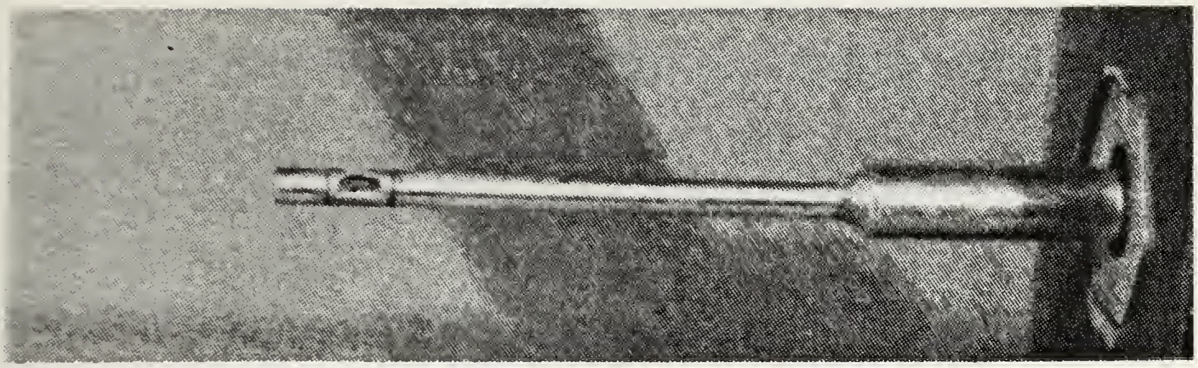


Fig. 4. Lower Plane Survey Probe

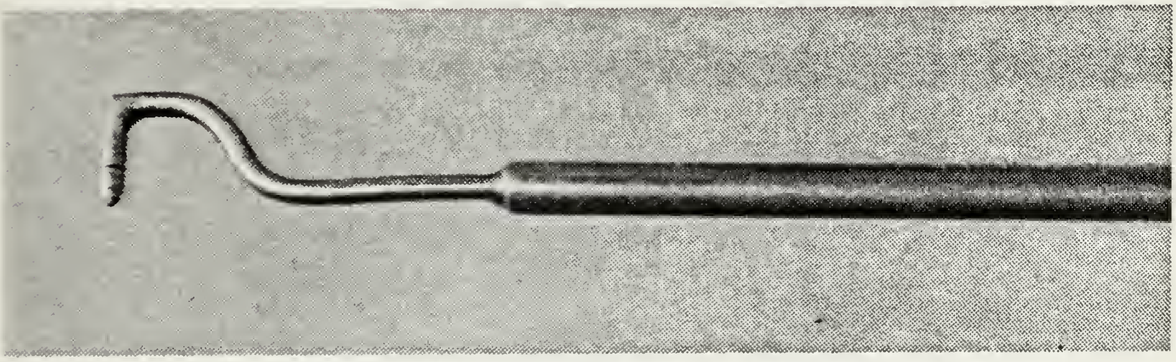


Fig. 5. Upper Plane Survey Probe

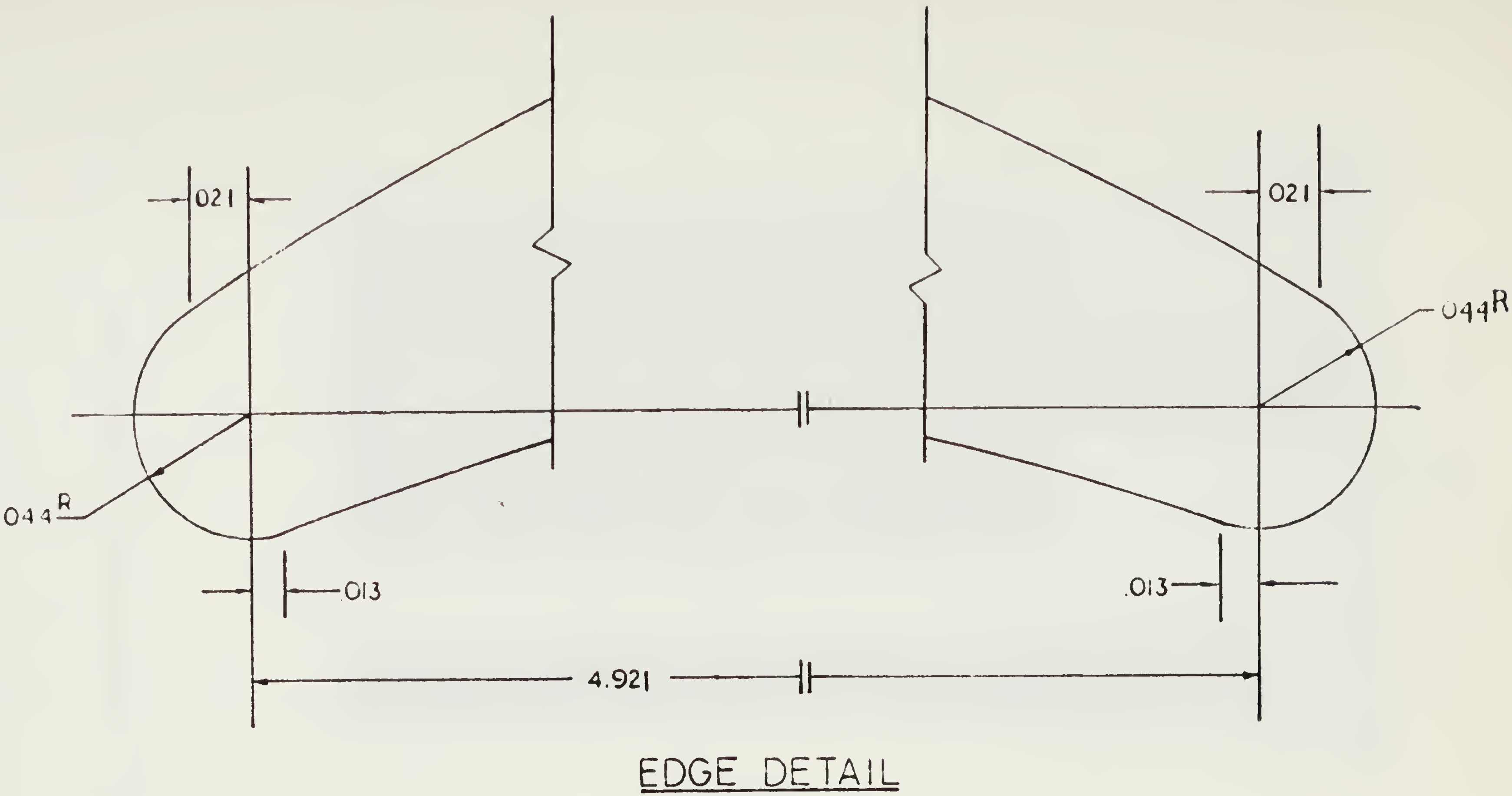


Fig. 6. Blade Edge Detail

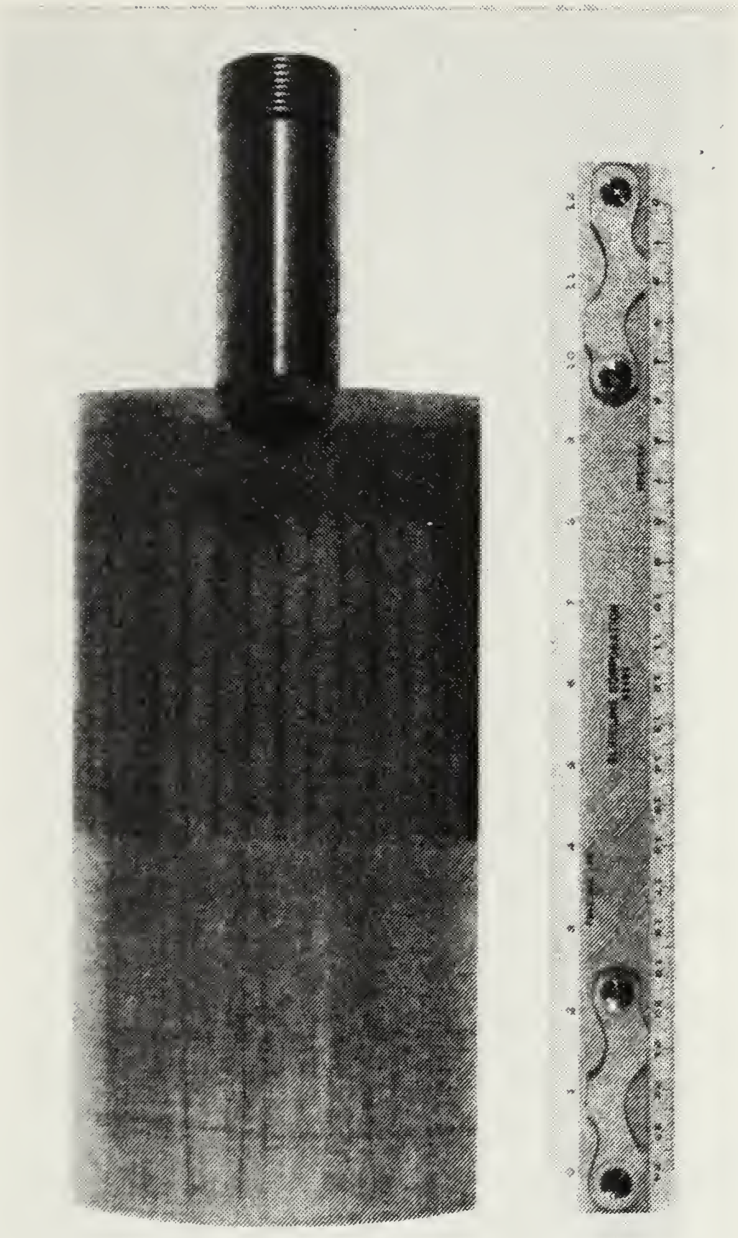


Fig. 7. Photograph of Instrumented Blade

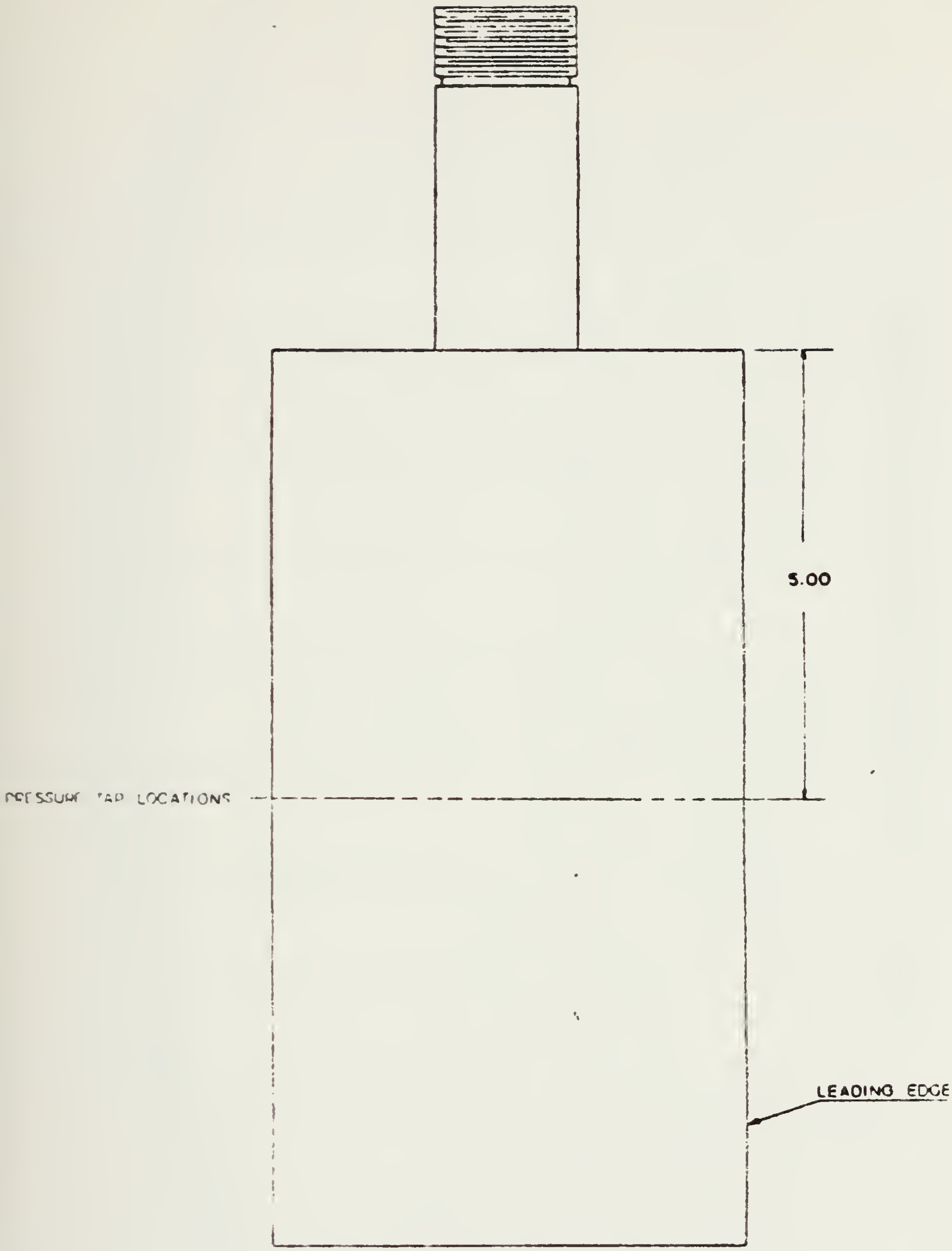


Fig. 8. Instrumented Blade

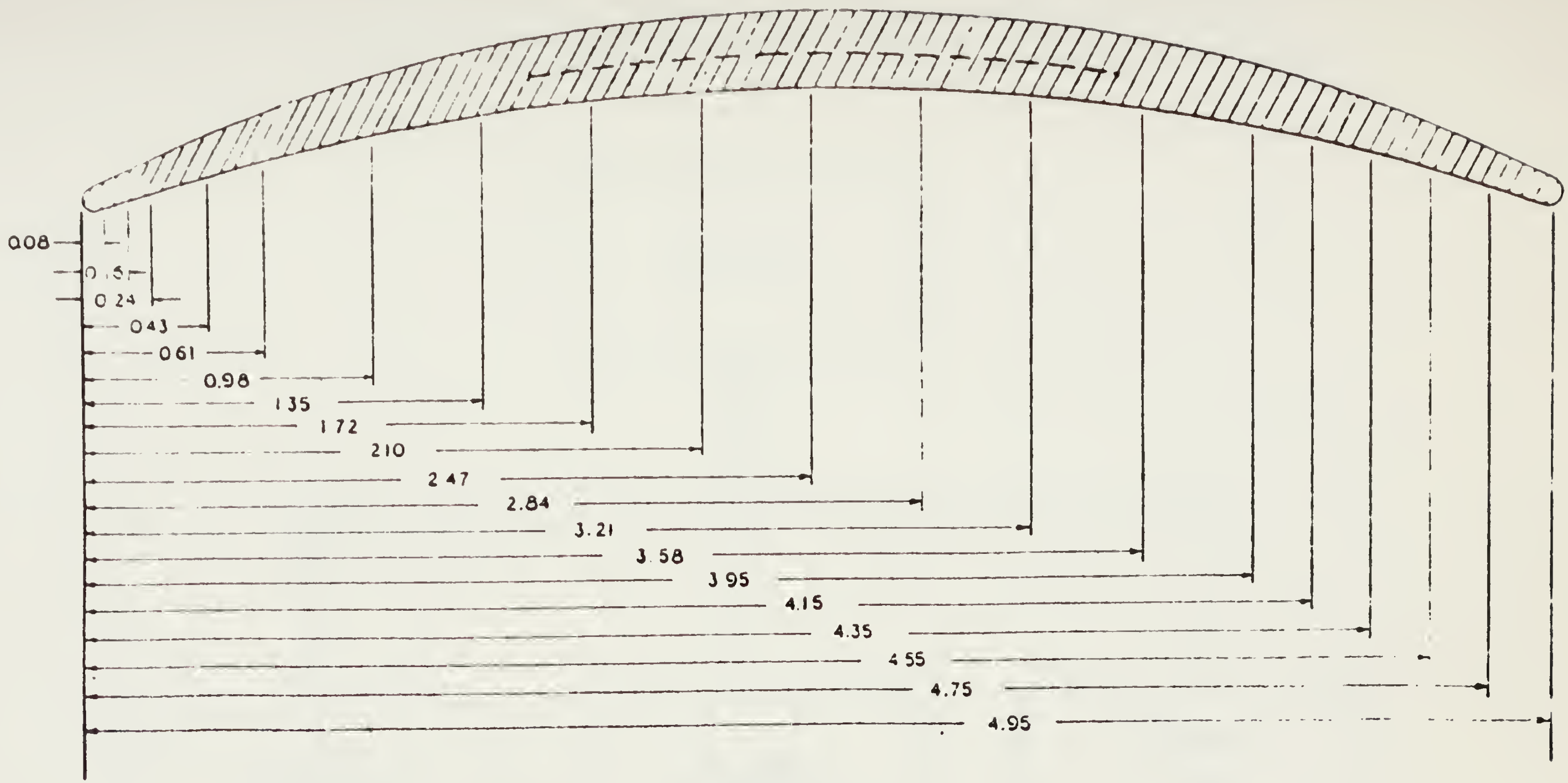


Fig. 9. Instrumented Blade Tap Locations

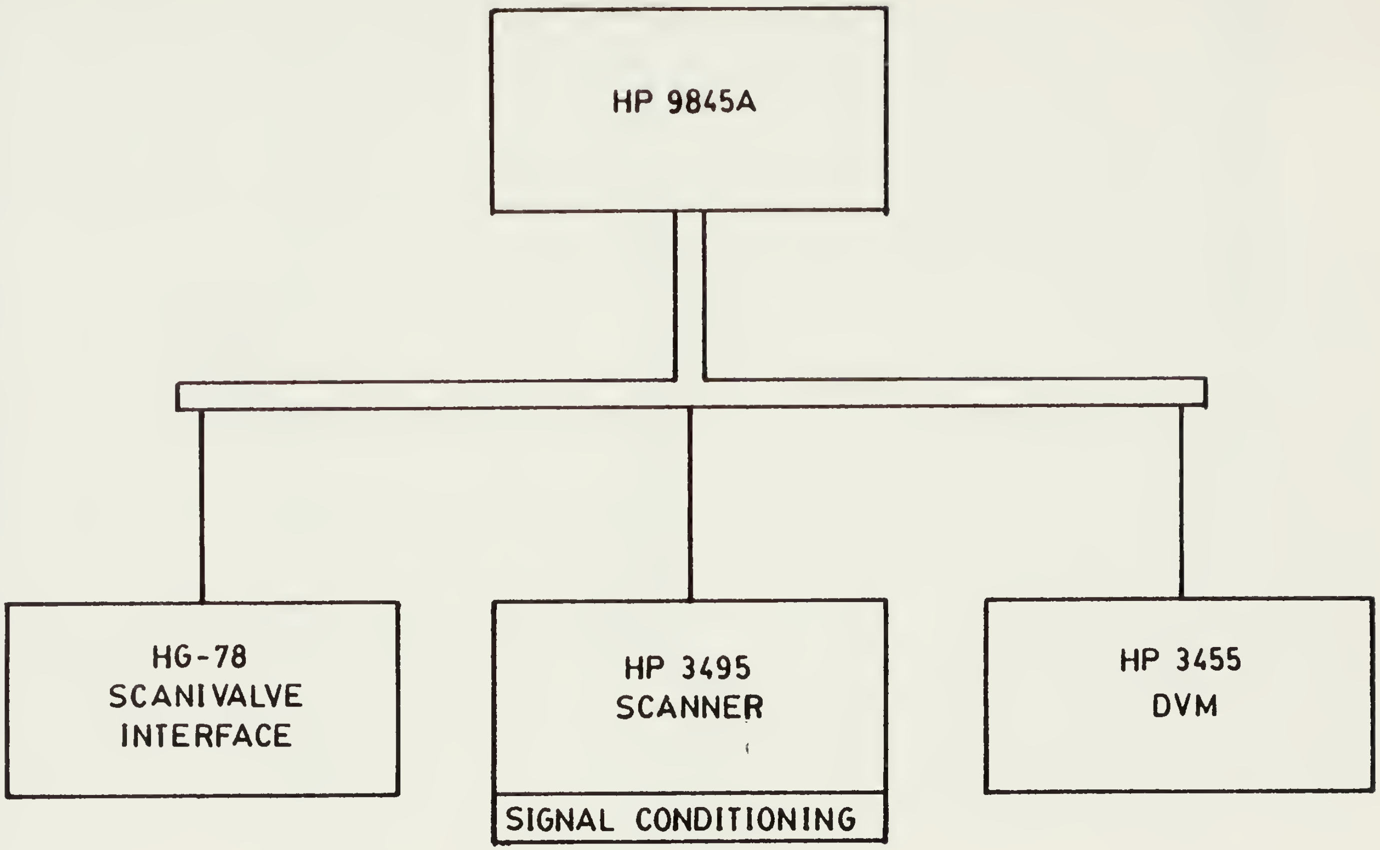


Fig. 10. Data Acquisition System

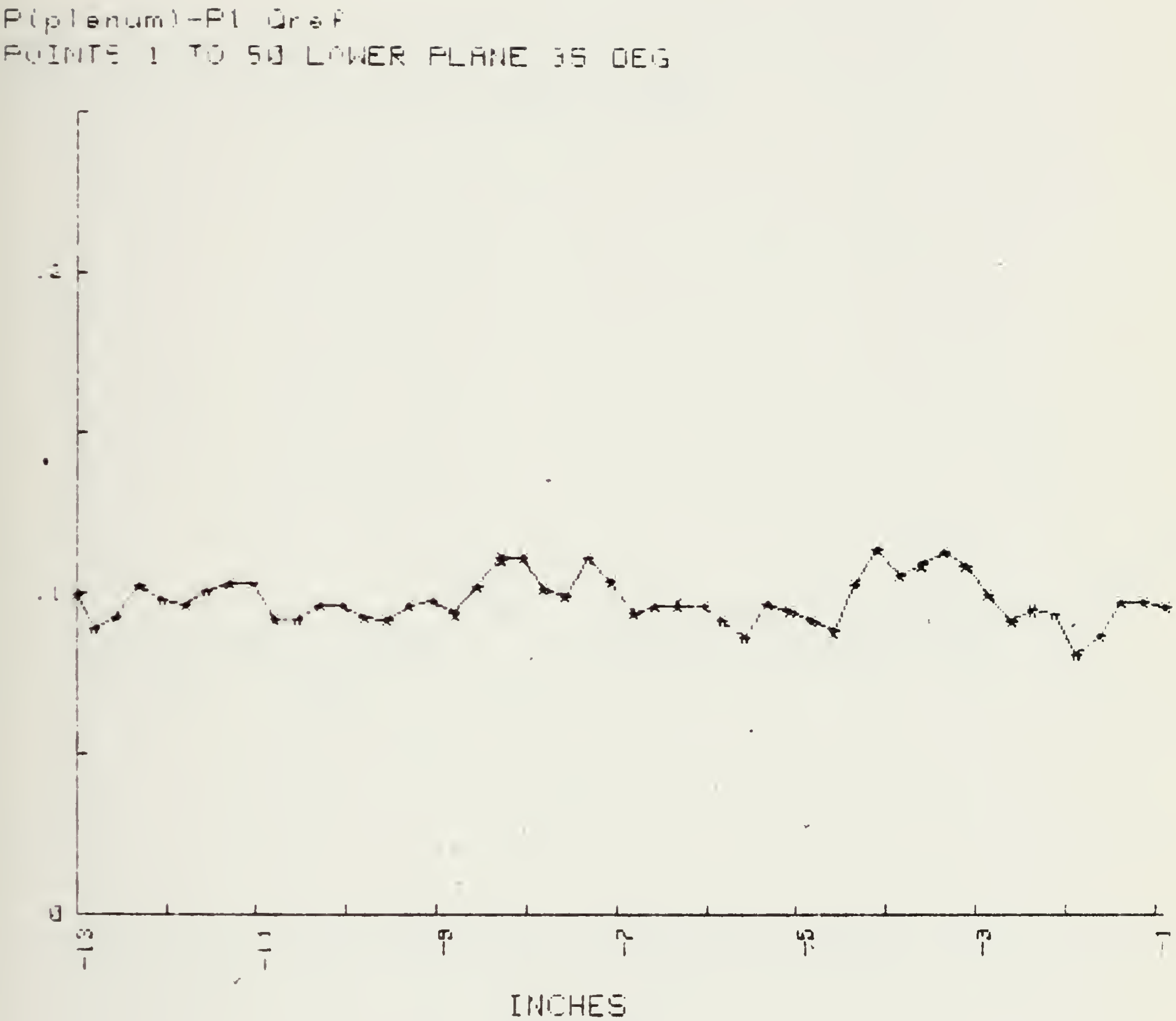


Fig. 11. Probe survey Data at Midspan of Lower Plane End Walls at 35°, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

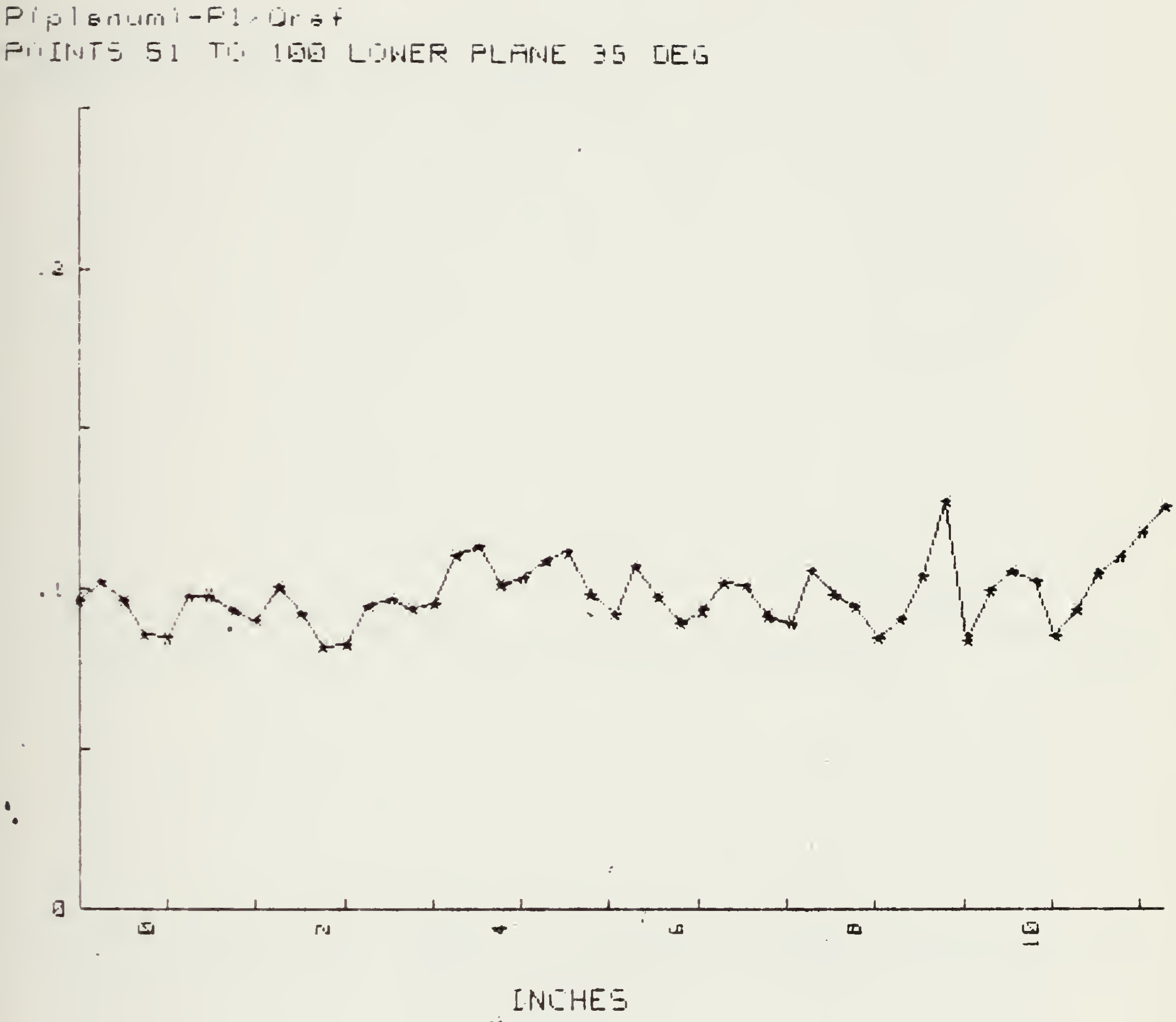


Fig. 12. Probe Survey Data at Midspan of Lower Plane End Walls at 35°, Points 51 to 100 $(P_{PLENUM} - P_t)/Q_{ref}$

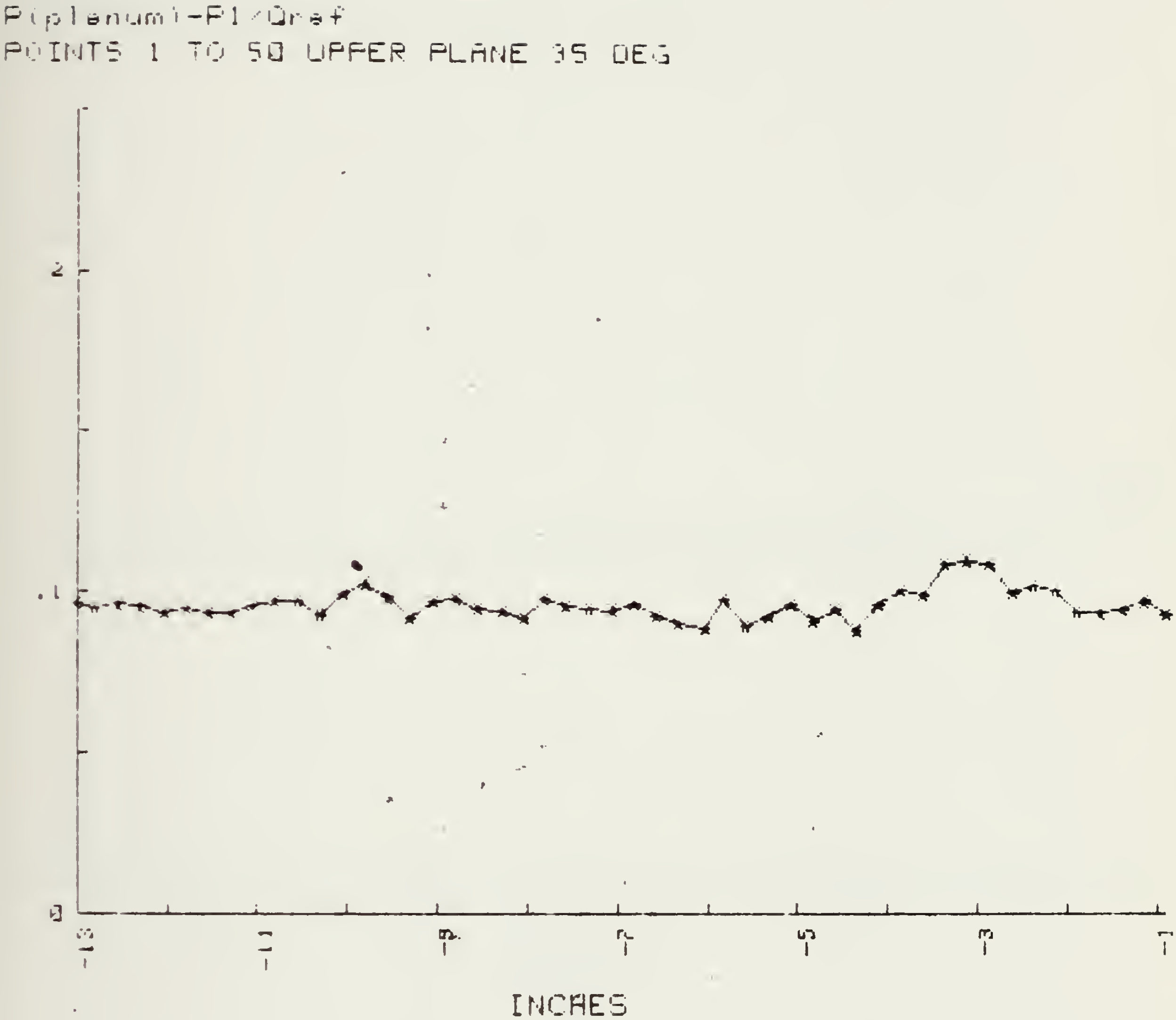


Fig. 13. Probe Survey Data at Midspan of Upper Plane End Walls at 35°, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

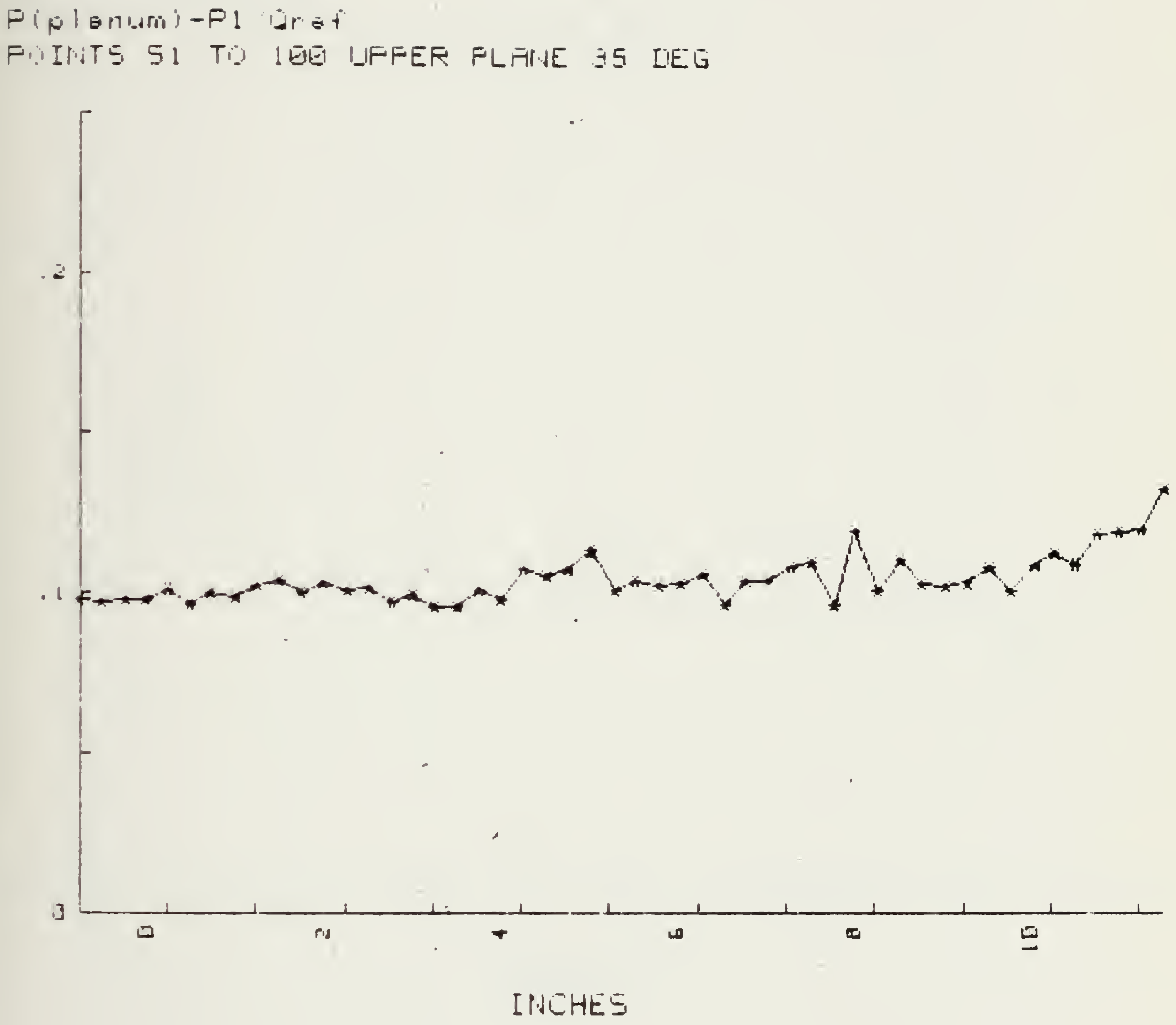


Fig. 14. Probe Survey Data at Midspan of Upper Plane End Walls at 35°, Points 51 to 100 $(P_{PLENUM} - P_t)/Q_{ref}$

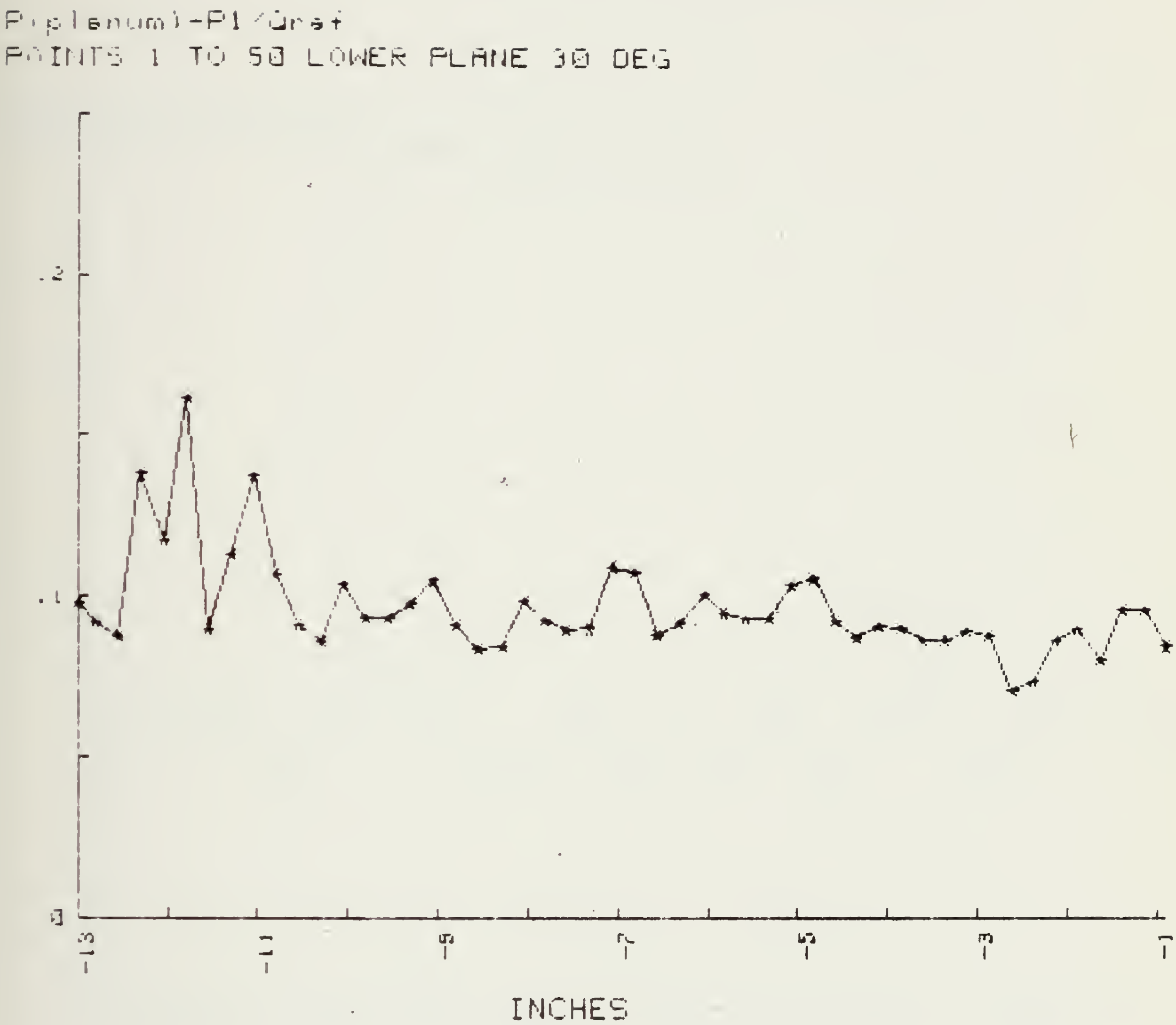


Fig. 15. Probe Survey Data at Midspan of Lower Plane End Walls at 30°, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

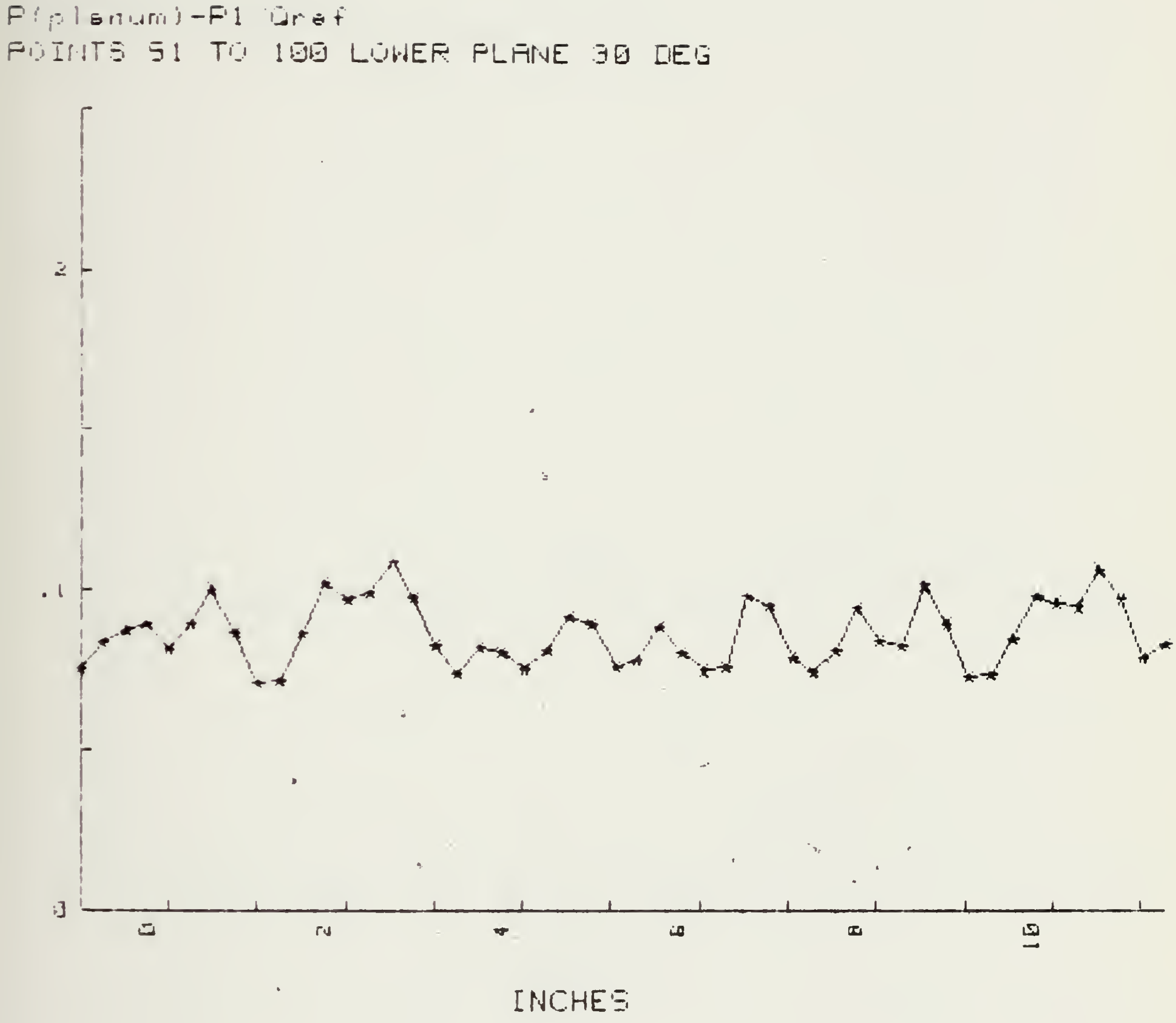


Fig. 16. Probe Survey Data at Midspan of Lower Plane End Walls at 30°, Points 51 to 100 $(P_{PLENUM} - P_t)/Q_{ref}$

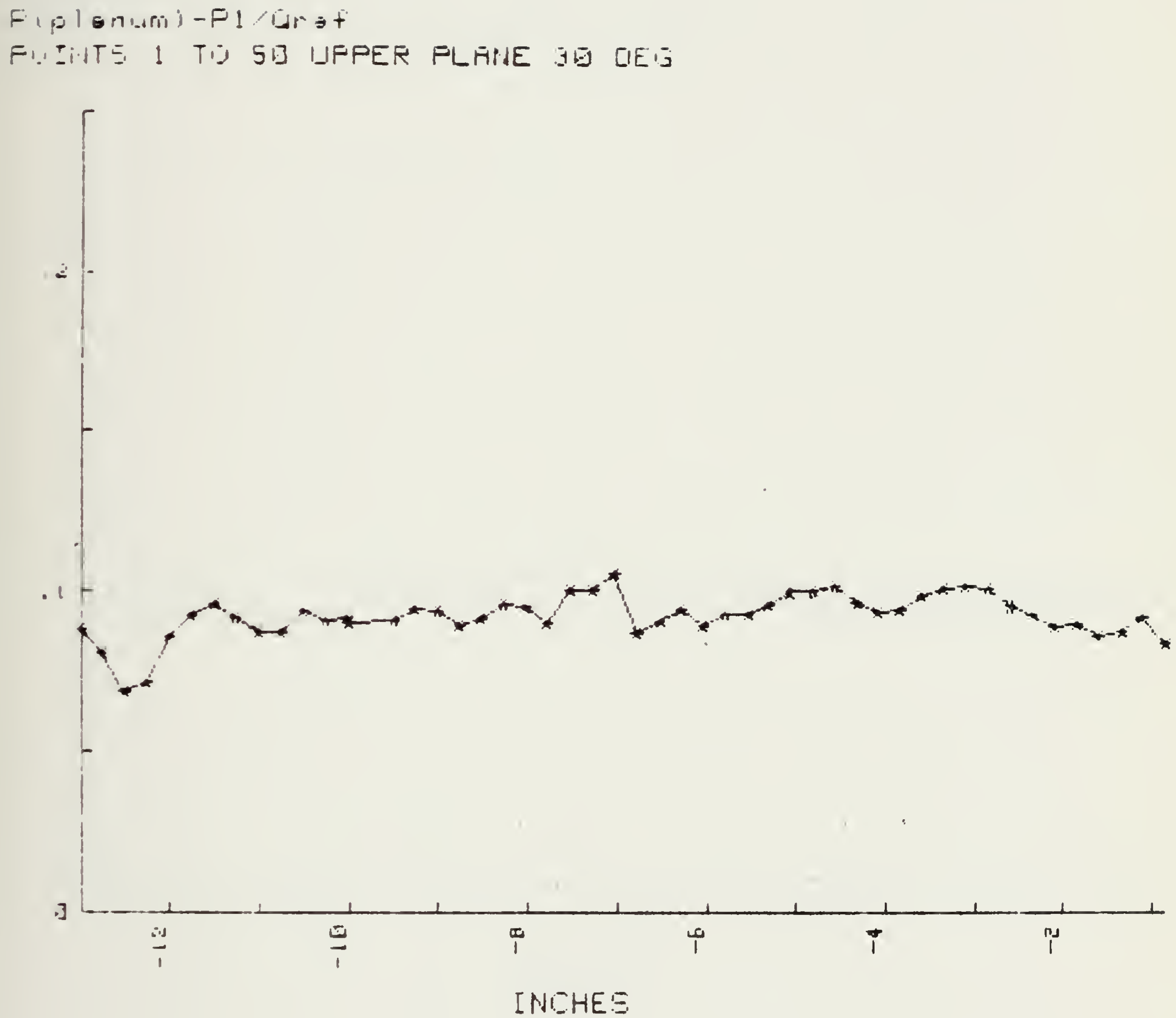


Fig. 17. Probe Survey Data at Midspan of Upper Plane End Walls at 30°, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

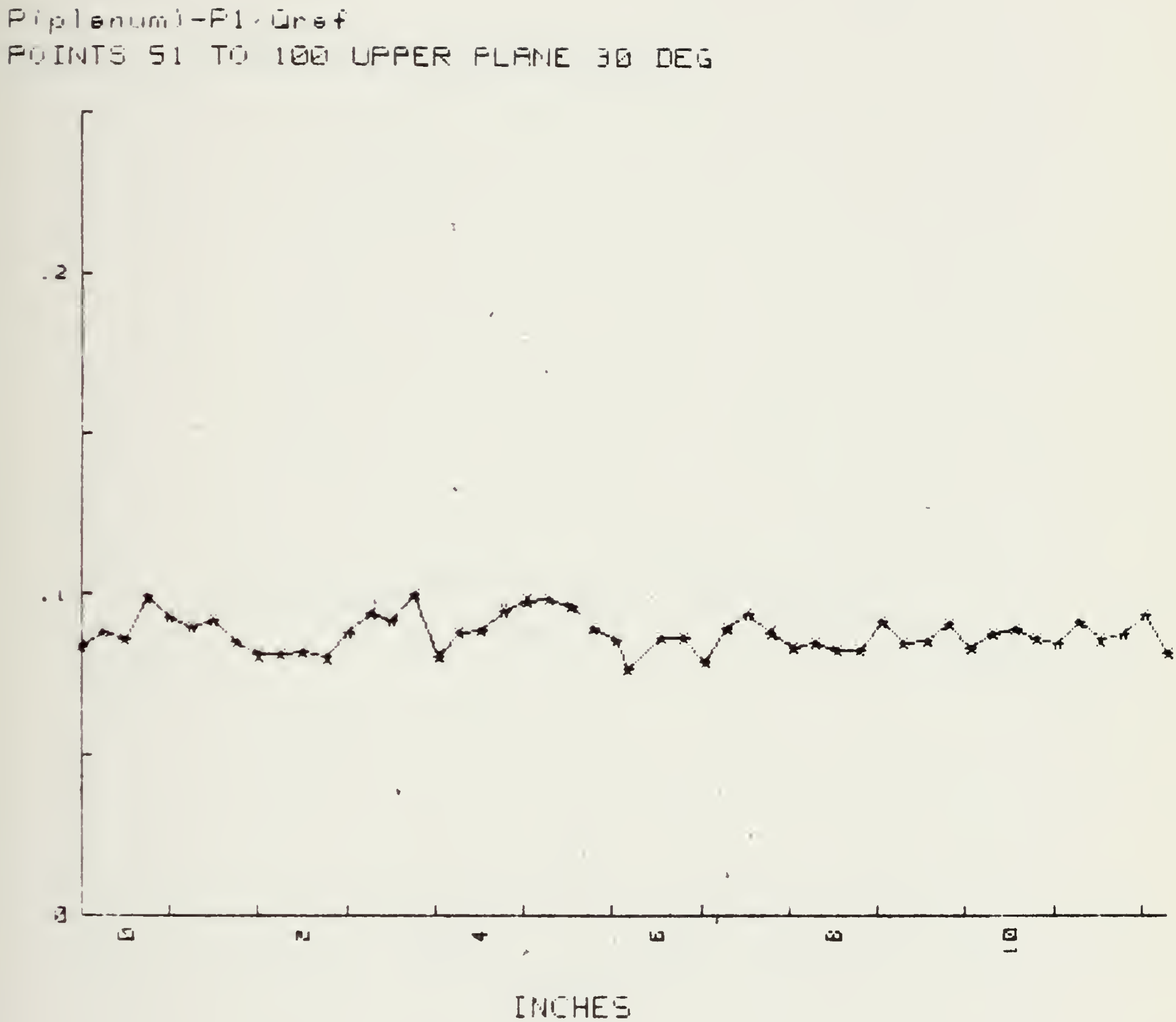


Fig. 18. Probe Survey Data at Midspan of Upper Plane End Walls at 30°, Points 51 to 100 $(P_{PLENUM} - P_t)/Q_{ref}$

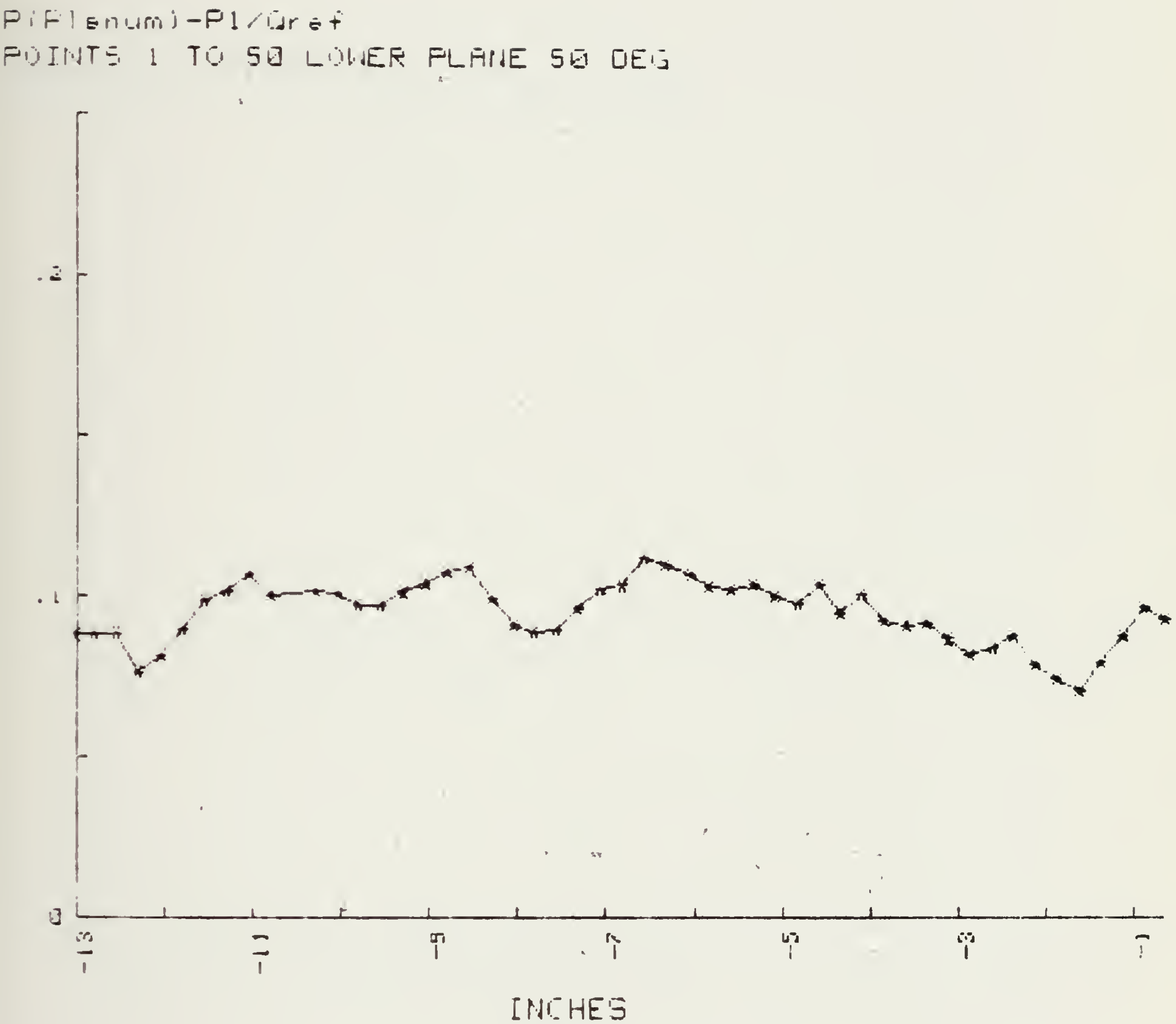


Fig. 19. Probe Survey Data at Midspan of Lower Plane End Walls at 50°, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

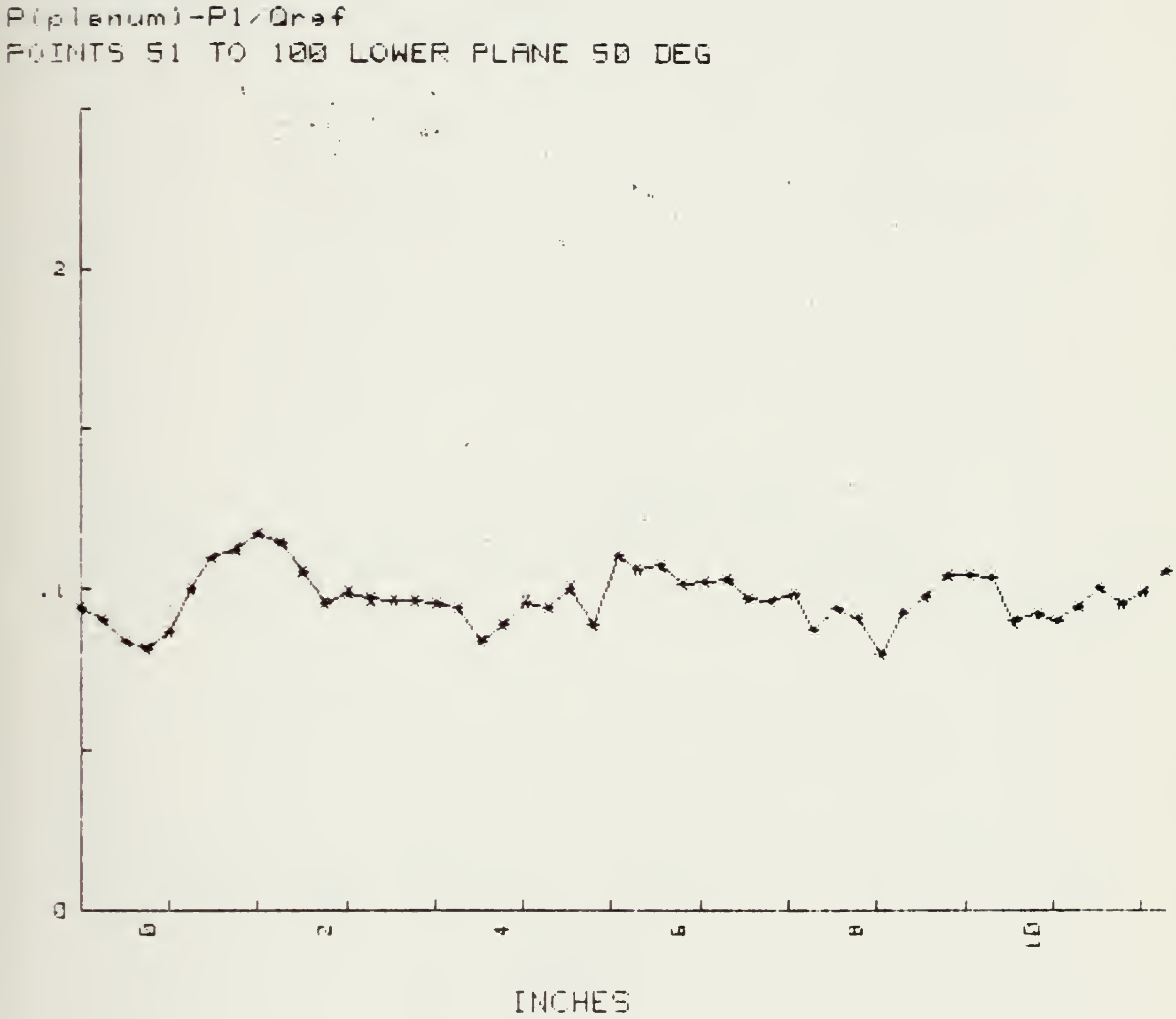


Fig. 20. Probe Survey Data at Midspan of Lower Plane End Walls at 50°, Points 51 to 100 $(P_{PLENUM} - P_t)/Q_{ref}$

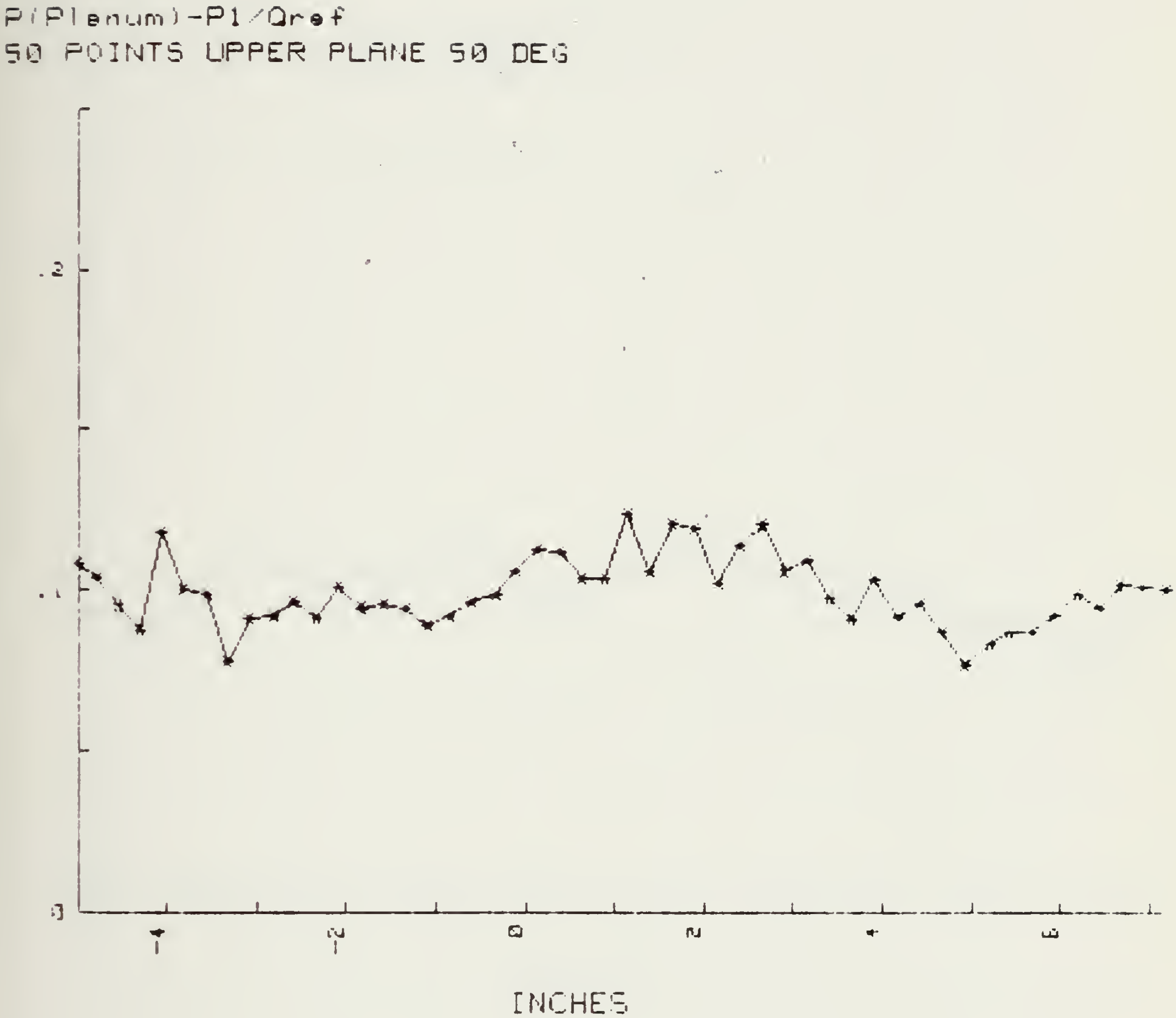


Fig. 21. Probe Survey Data at Midspan of Upper Plane End Walls at 50°
$(P_{PLENUM} - P_t)/Q_{ref}$

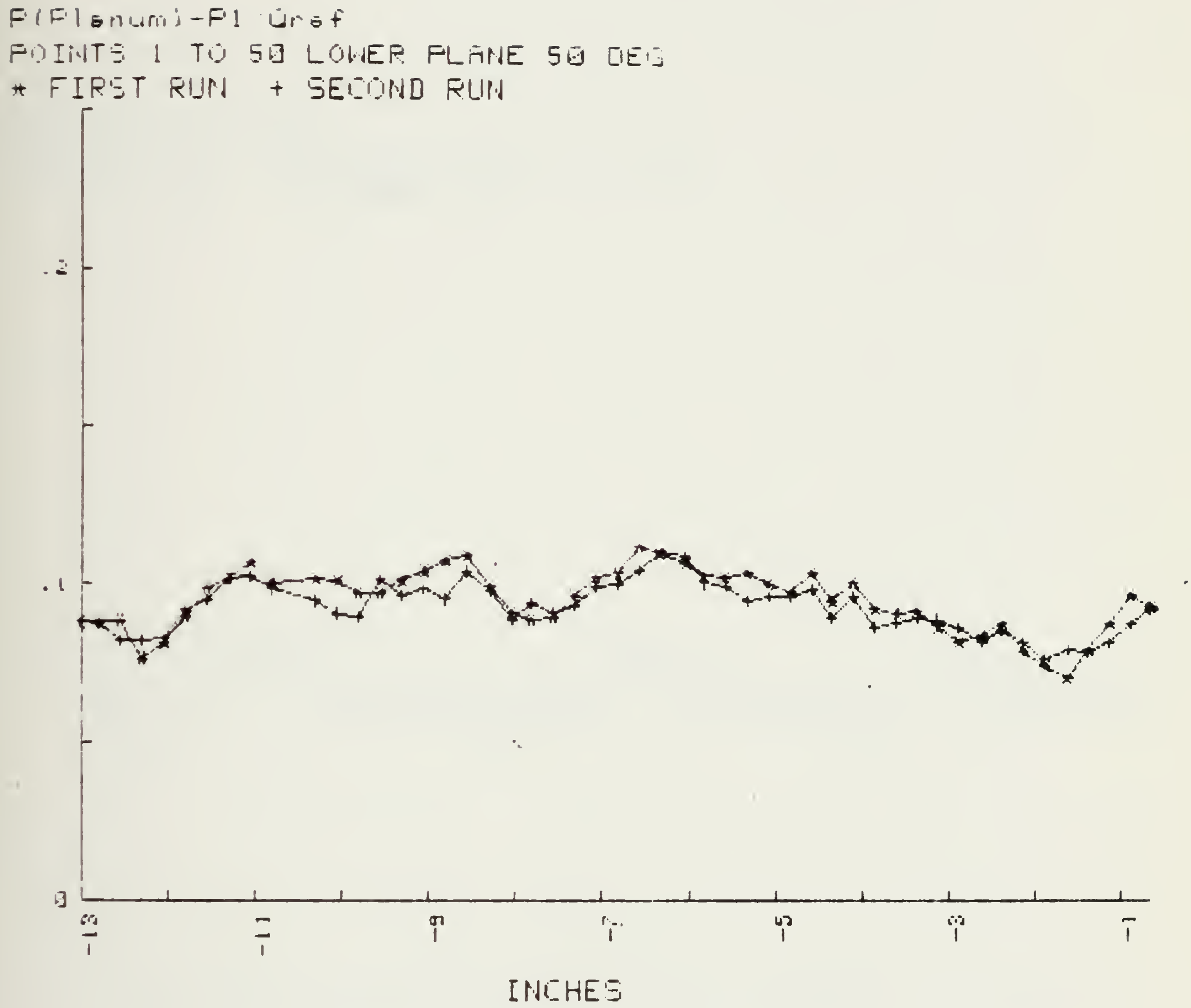


Fig. 22. Probe Survey Data at Midspan at Lower Plane End Walls at 50°, Two Runs, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

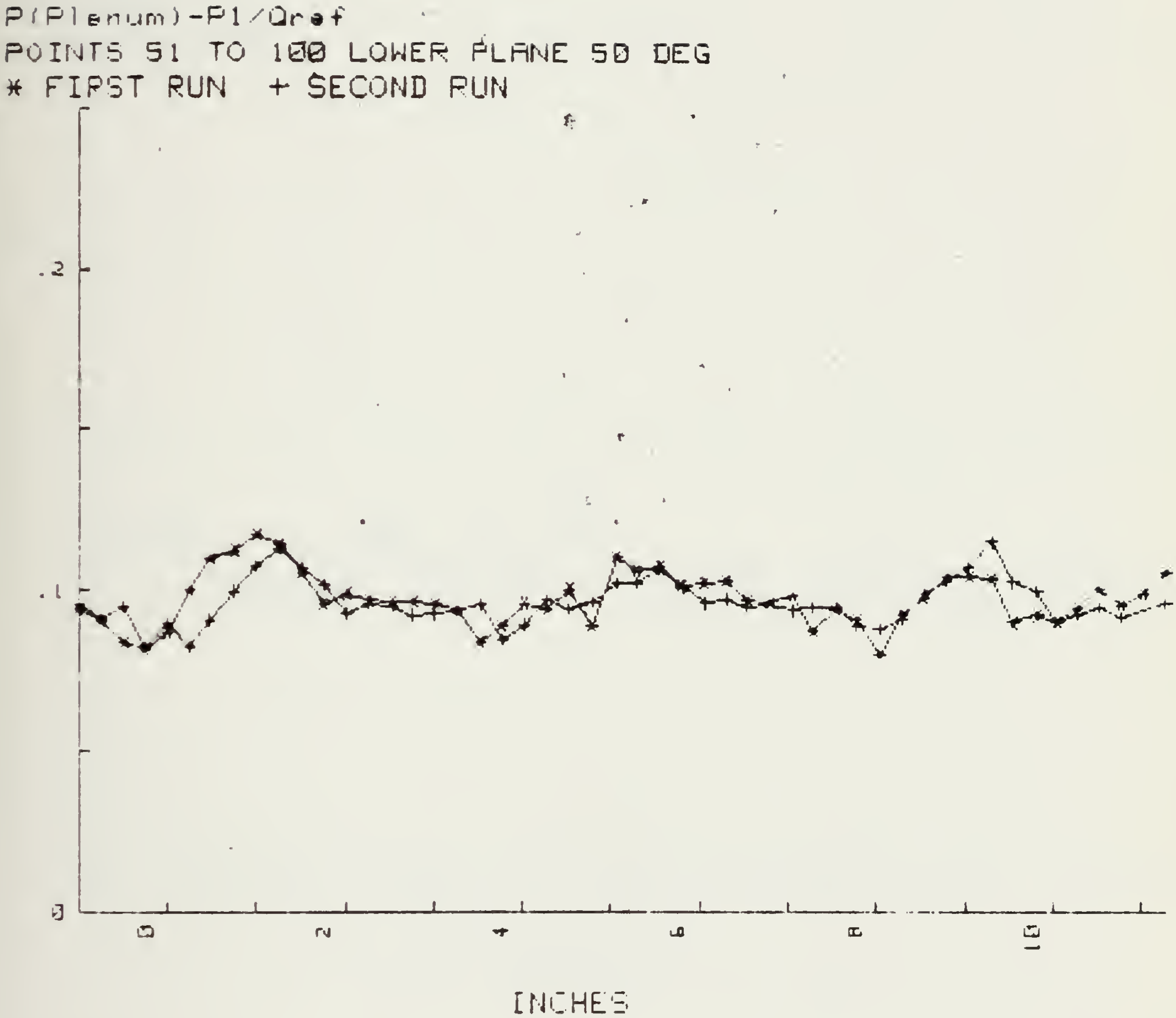


Fig. 23. Probe Survey Data at Midspan at Lower Plane End Walls at 50°, Two Runs, Points 51 to 100 $(P_{PLENUM} - P_t)/Q_{ref}$

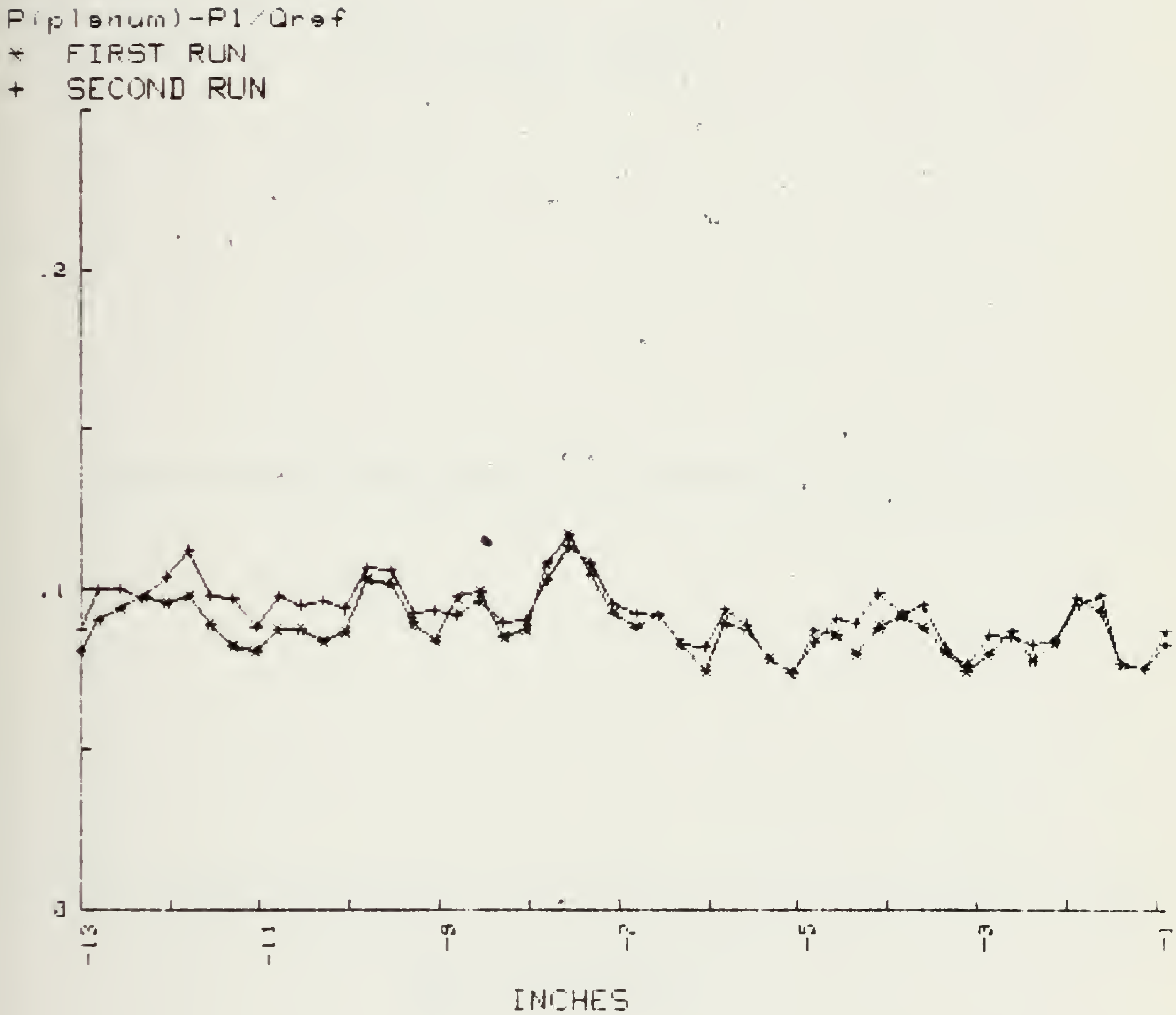


Fig. 24. Probe Survey Data at Midspan at Lower Plane End Walls at 30°, Two Runs, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

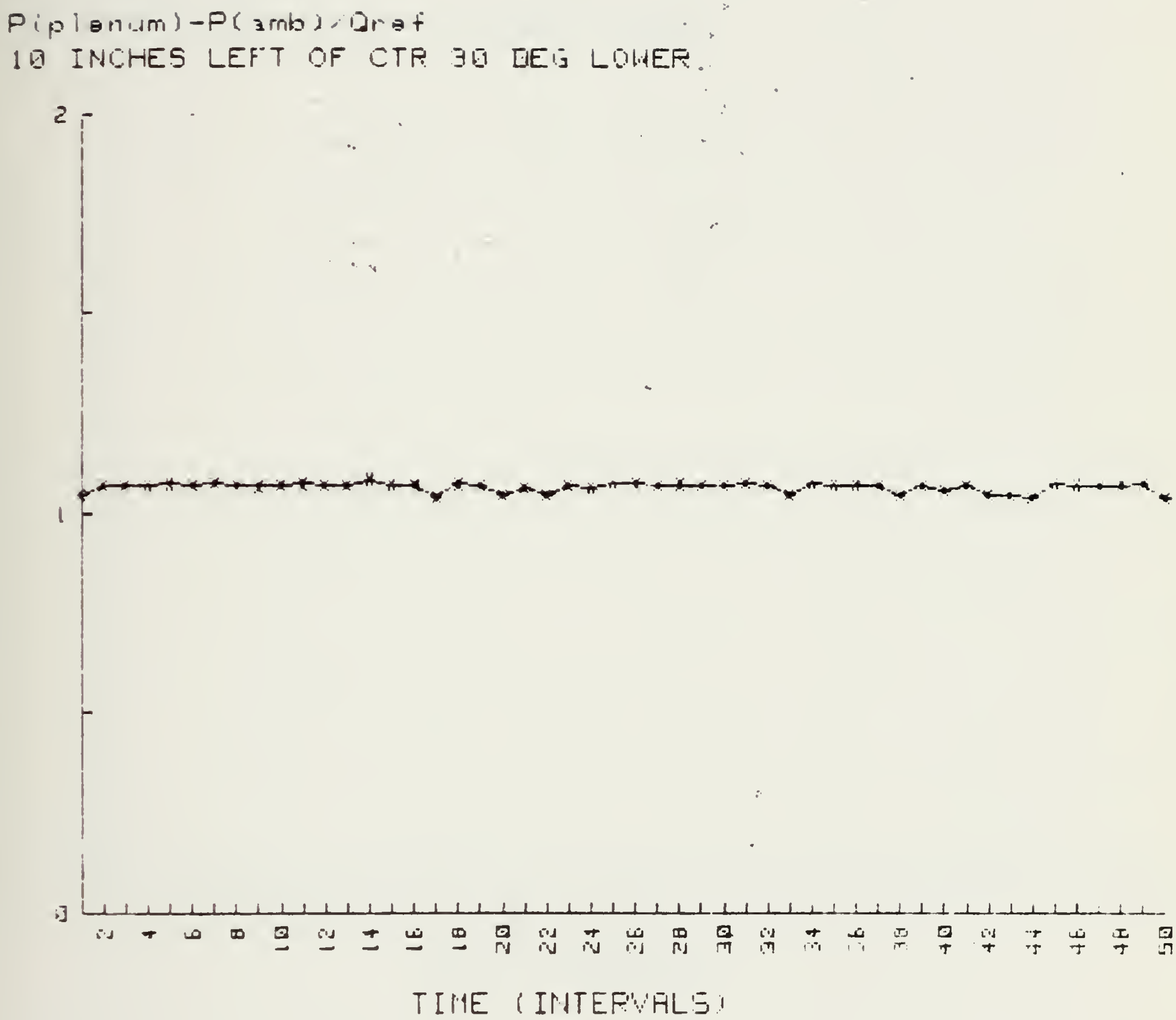


Fig. 25. Repetitive Samples with Fixed Probe Position (10" Left of CTR Midspan, End Walls 30°, Lower Plane $(P_{PLENUM} - P_{AMB})/Q_{ref}$)

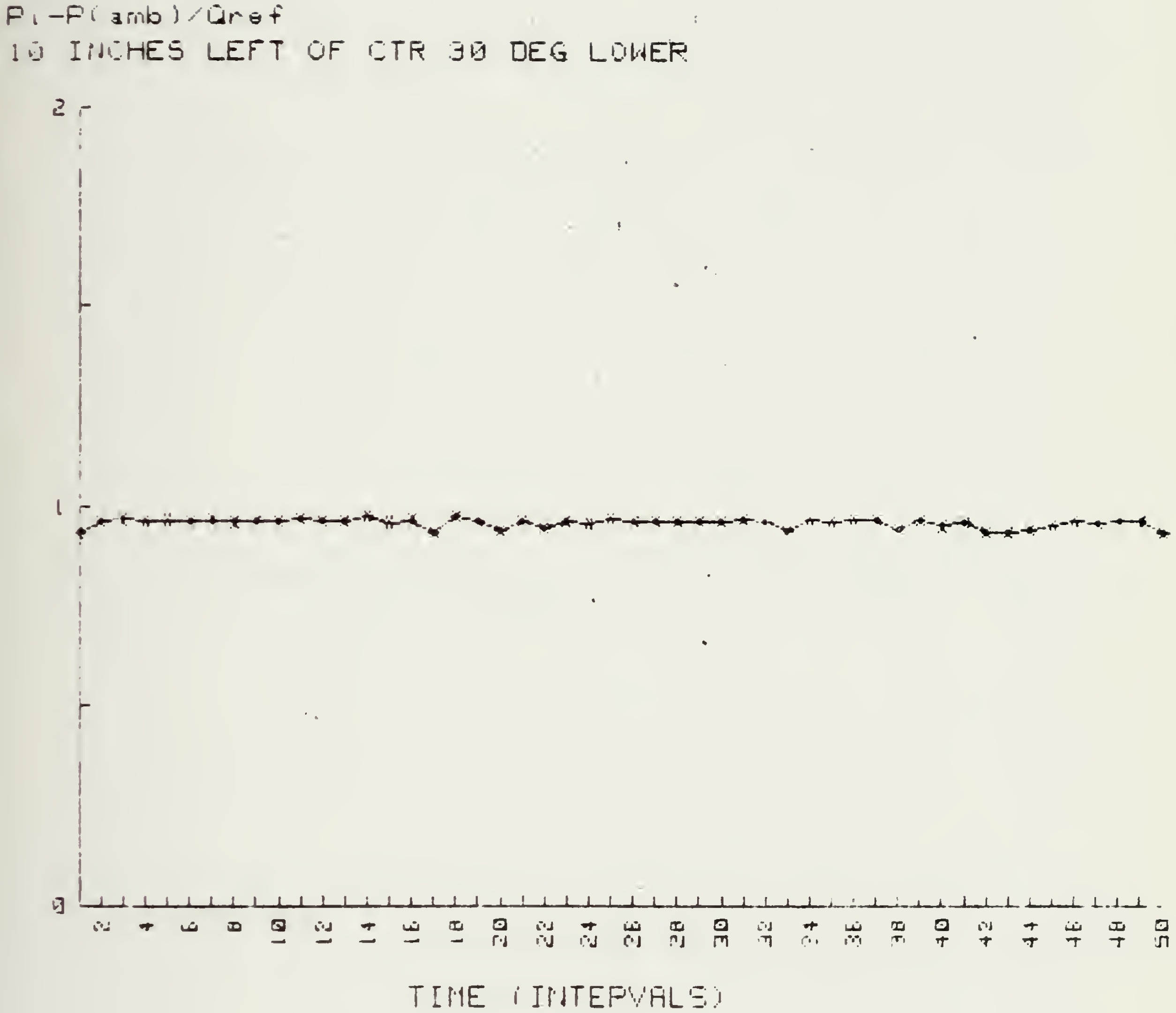


Fig. 26. Repetitive Samples with Fixed Probe Position (10" Left of CTR Midspan, End Walls at 30°, Lower Plane $(P_t - P_{AMB})/Q_{ref}$)

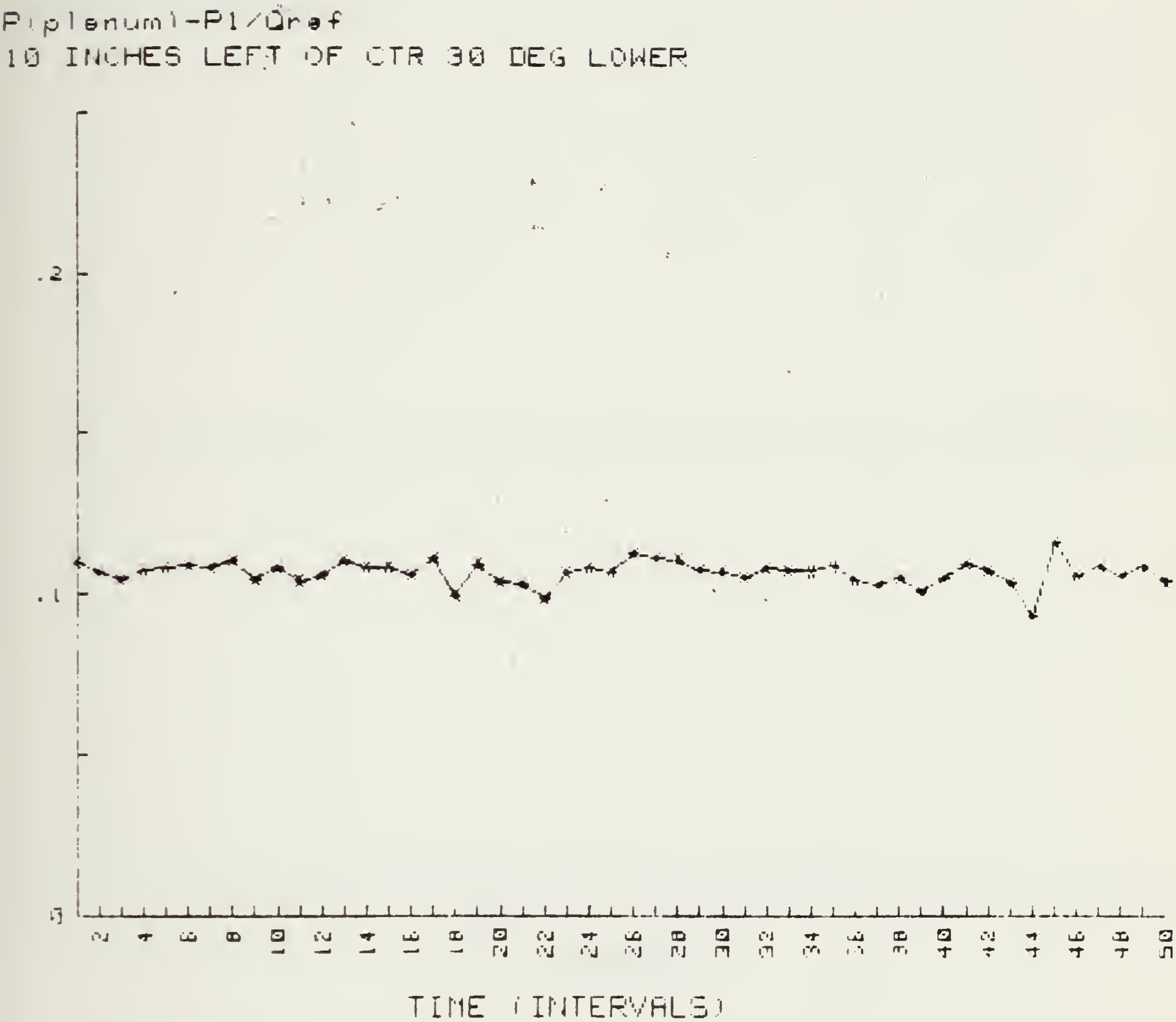


Fig. 27. Repetitive Samples with Fixed Probe Position (10" Left of CTR Midspan, End Walls at 30°, Lower Plane $(P_{PLENUM} - P_t)/Q_{ref}$

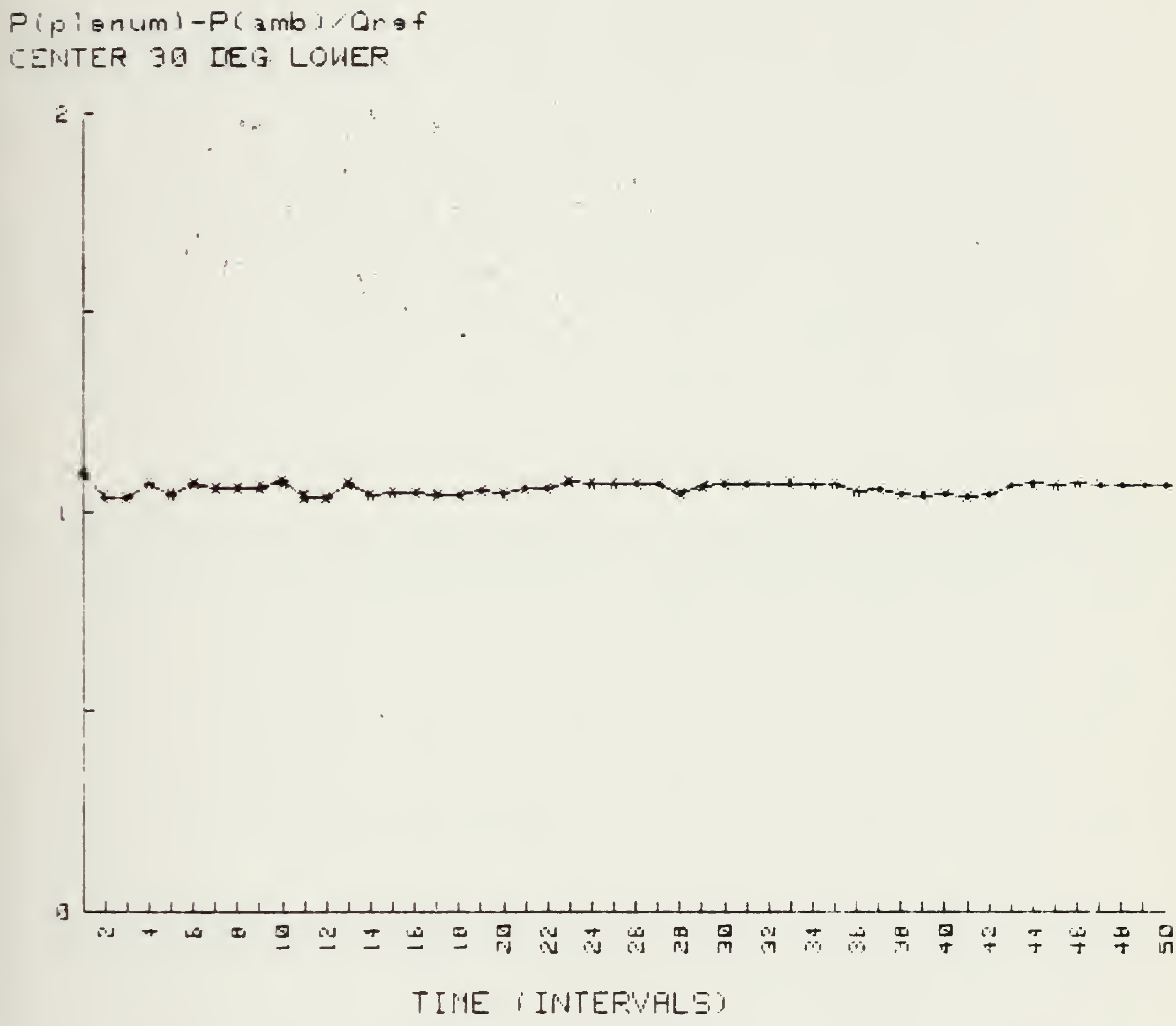


Fig. 28. Repetitive Samples with Fixed Probe Position (on Centerline at Midspan, End Walls at 30°, Lower Plane $(P_{PLENUM} - P_{AMB})/Q_{ref}$)

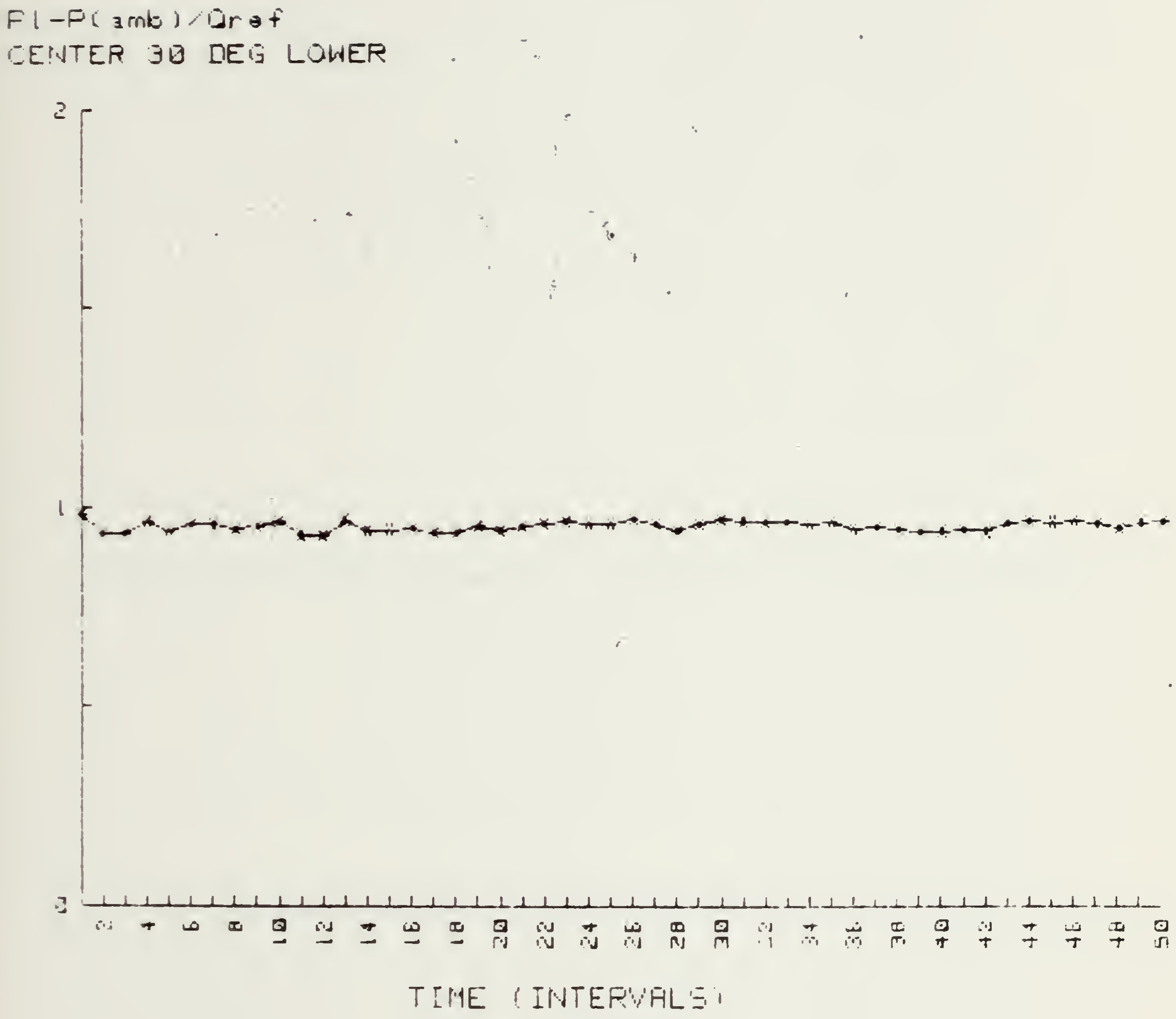


Fig. 29. Repetitive Samples with Fixed Probe Position (on Centerline at Midspan, End Walls at 30°, Lower Plane $(P_t - P_{AMB})/Q_{ref}$)

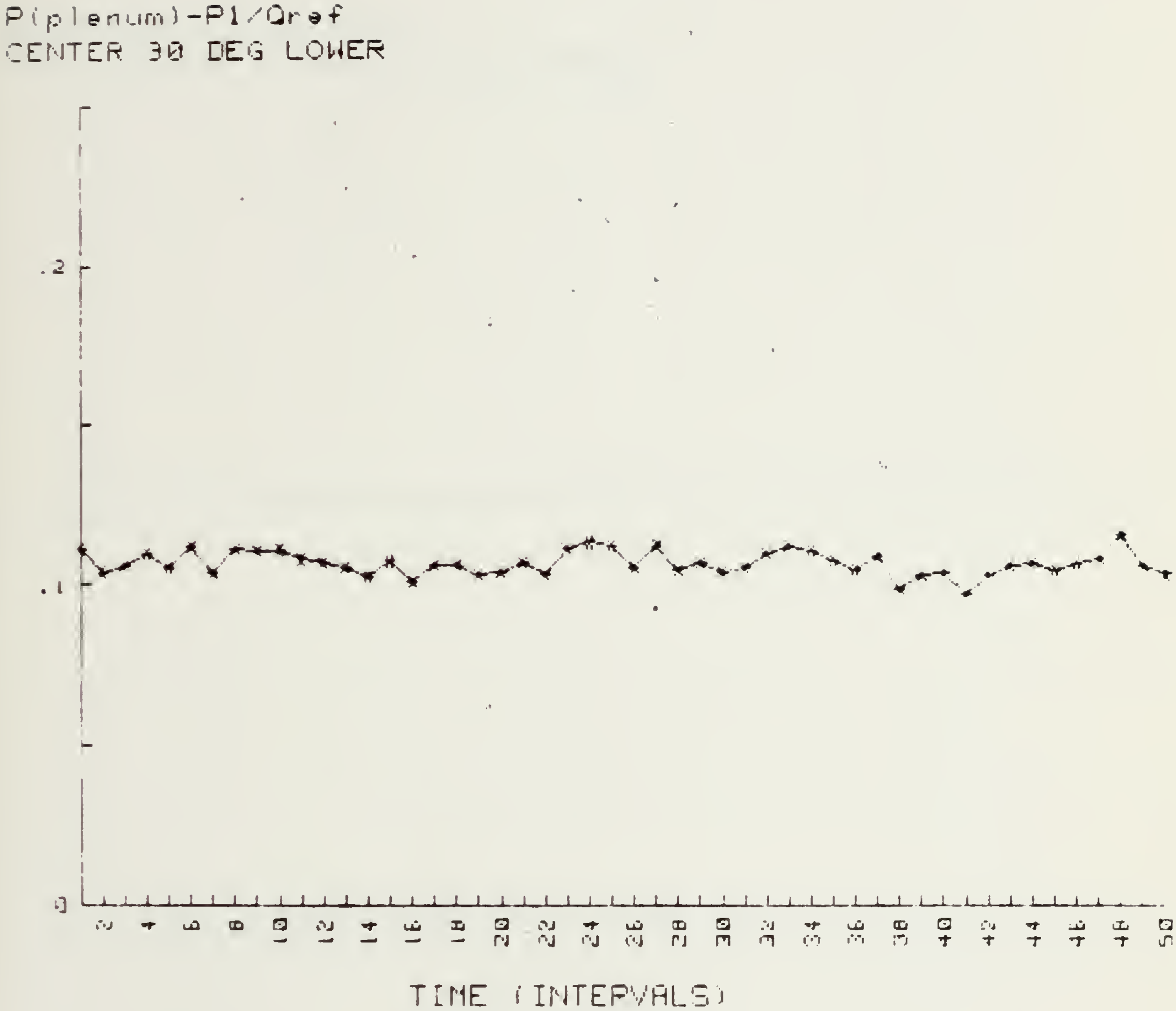


Fig. 30. Repetitive Samples with Fixed Probe Position (on Centerline at Midspan, End Walls at 30°, Lower Plane $(P_{PLENUM} - P_t)/Q_{ref})$

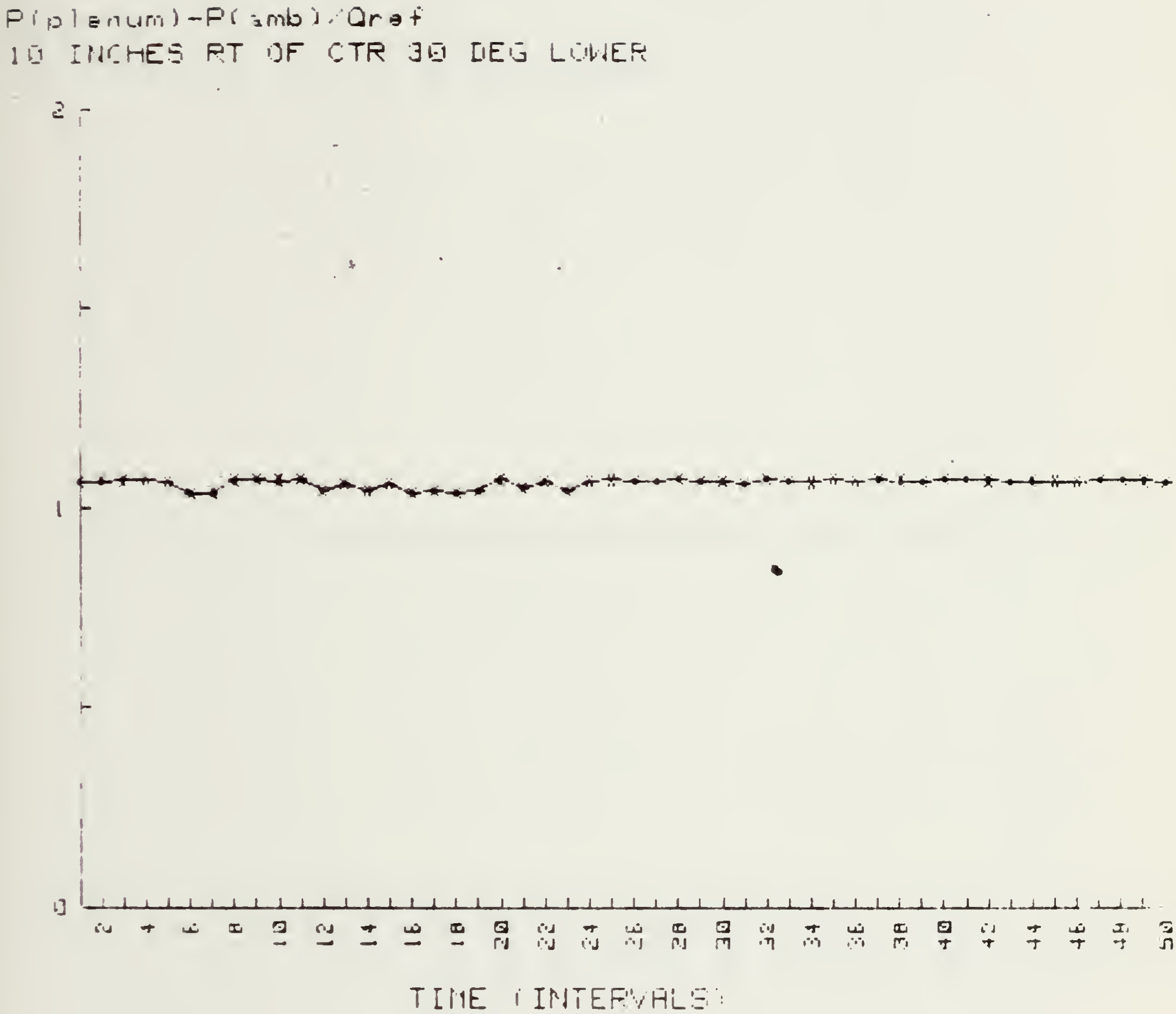


Fig. 31. Repetitive Samples with Fixed Probe Position (10" Right of CTR Midspan, End Walls at 30°, Lower Plane $(P_{PLENUM} - P_{AMB})/Q_{ref})$

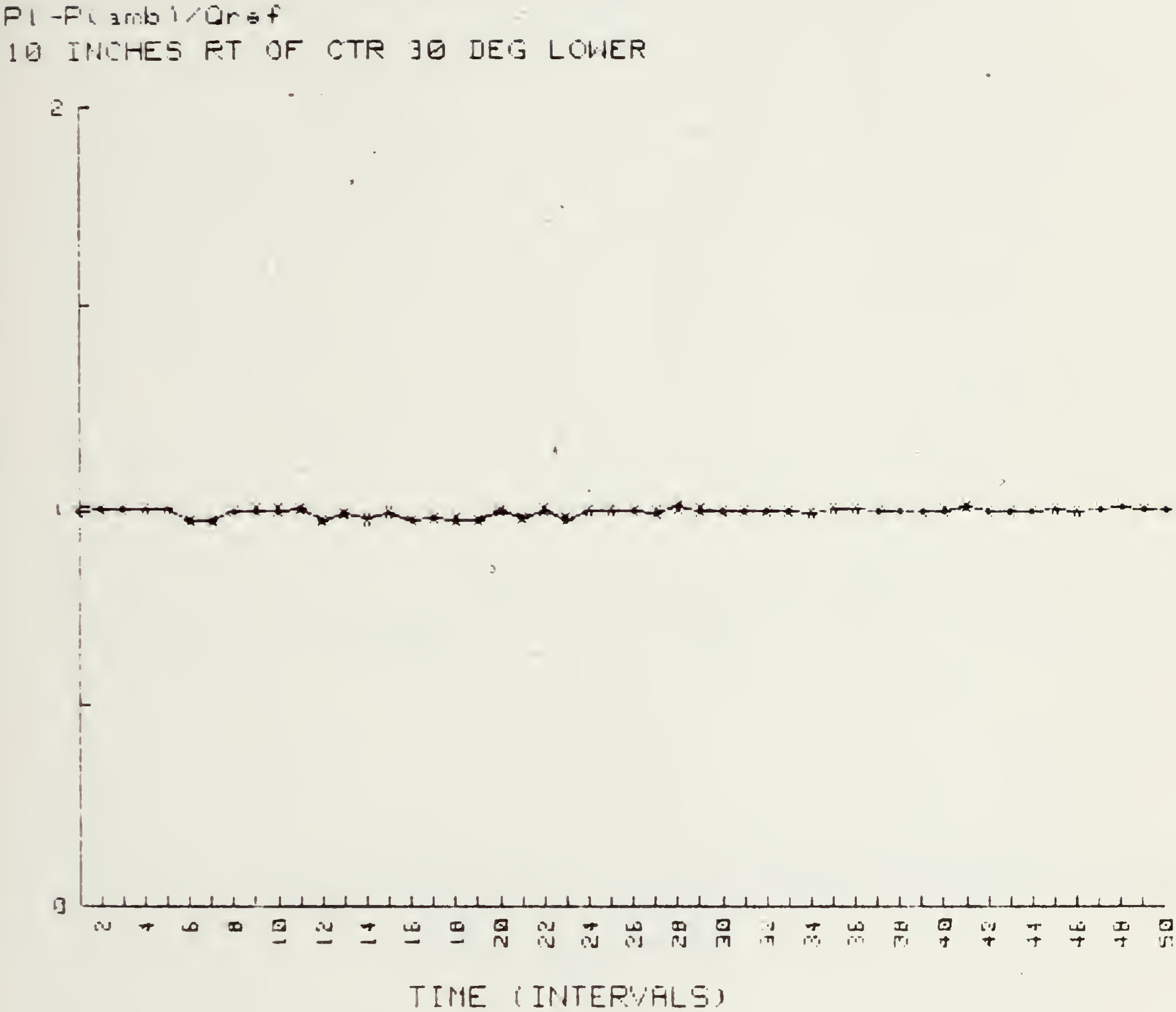


Fig. 32. Repetitive Samples with Fixed Probe Position (10" Right of CTR Midspan, End Walls at 30°, Lower Plane $(P_t - P_{AMB})/Q_{ref}$)

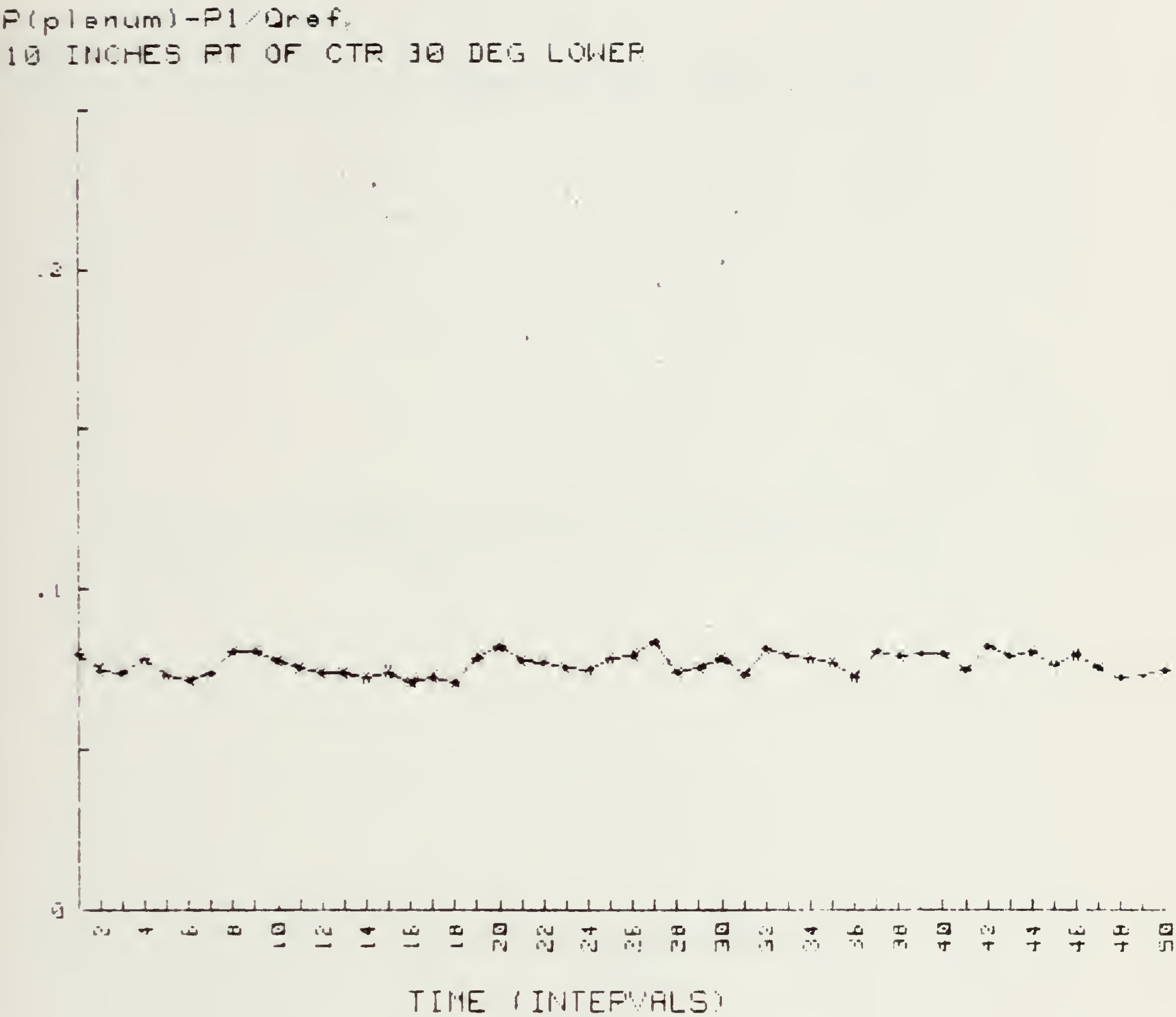


Fig. 33. Repetitive Samples with Fixed Probe Position (10" Right of CTR Midspan, End Walls at 30°, Lower Plane $(P_{PLENUM} - P_t)/Q_{ref}$)

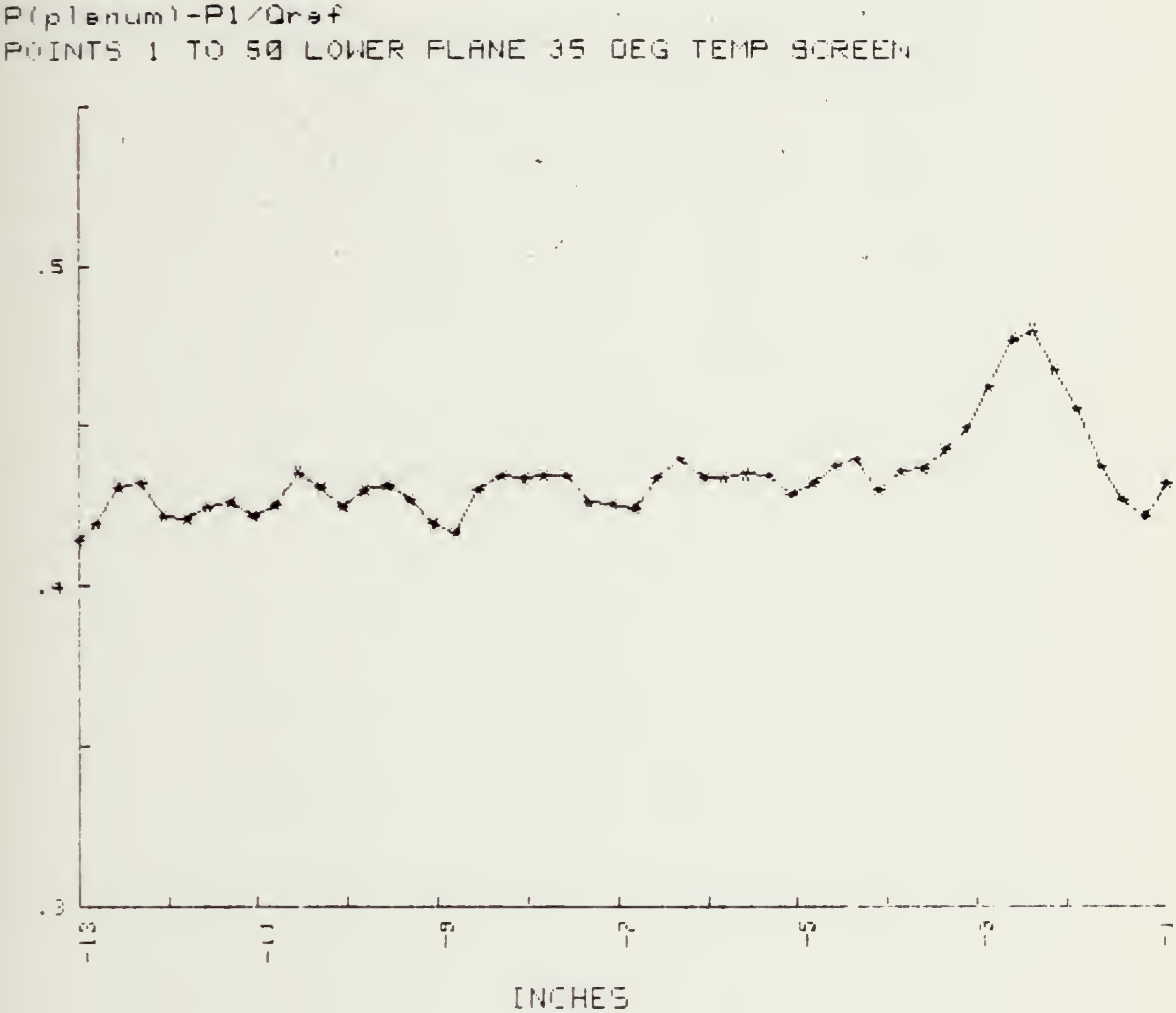


Fig. 34. Probe Survey Data at Midspan, Lower Plane 16 Mesh Screen, Walls at 35°, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

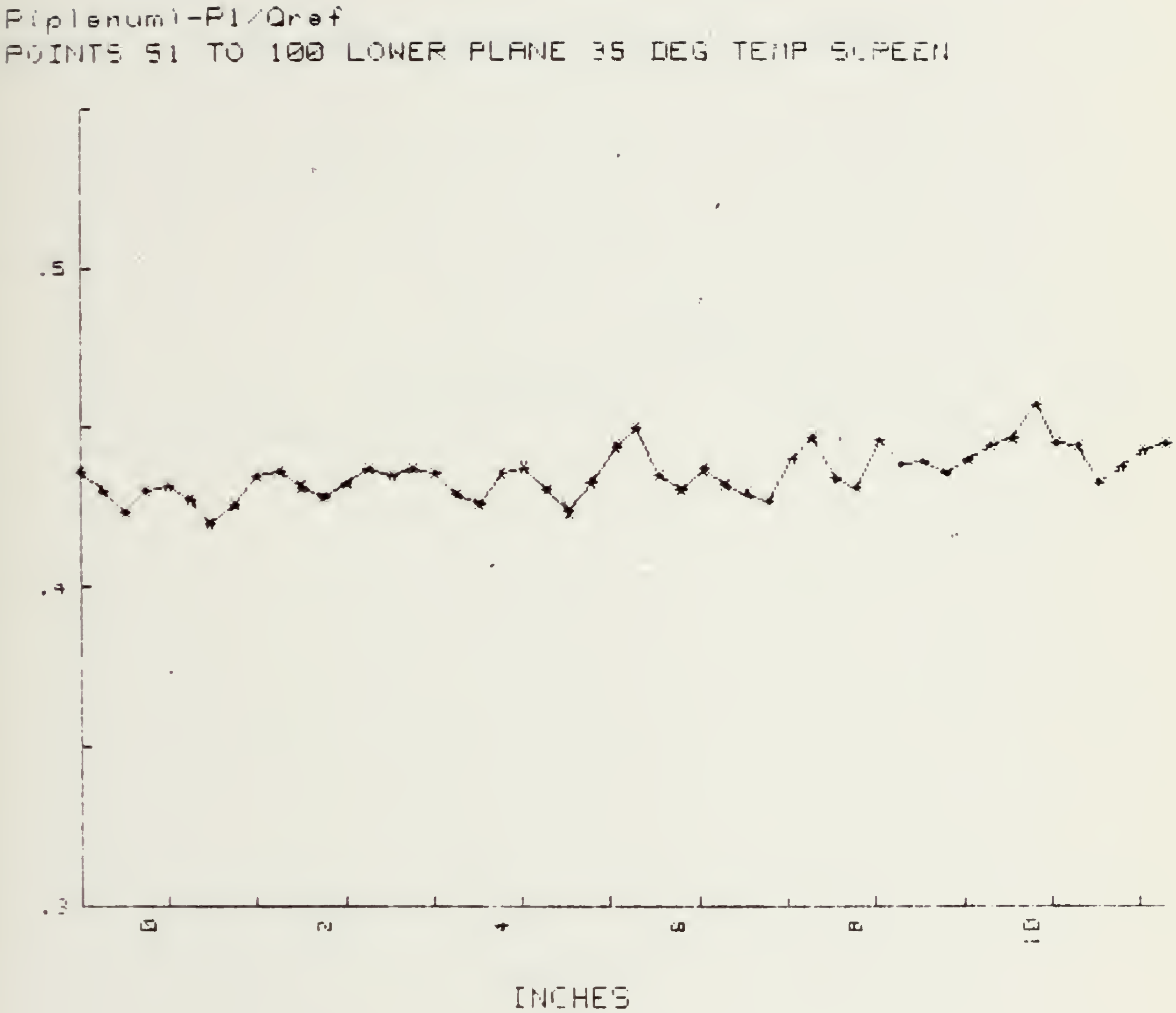


Fig. 35. Probe Survey Data at Midspan, Lower Plane 16 Mesh Screen, Walls at 35°, Points 51 to 100 $(P_{PLENUM} - P_t)/Q_{ref}$

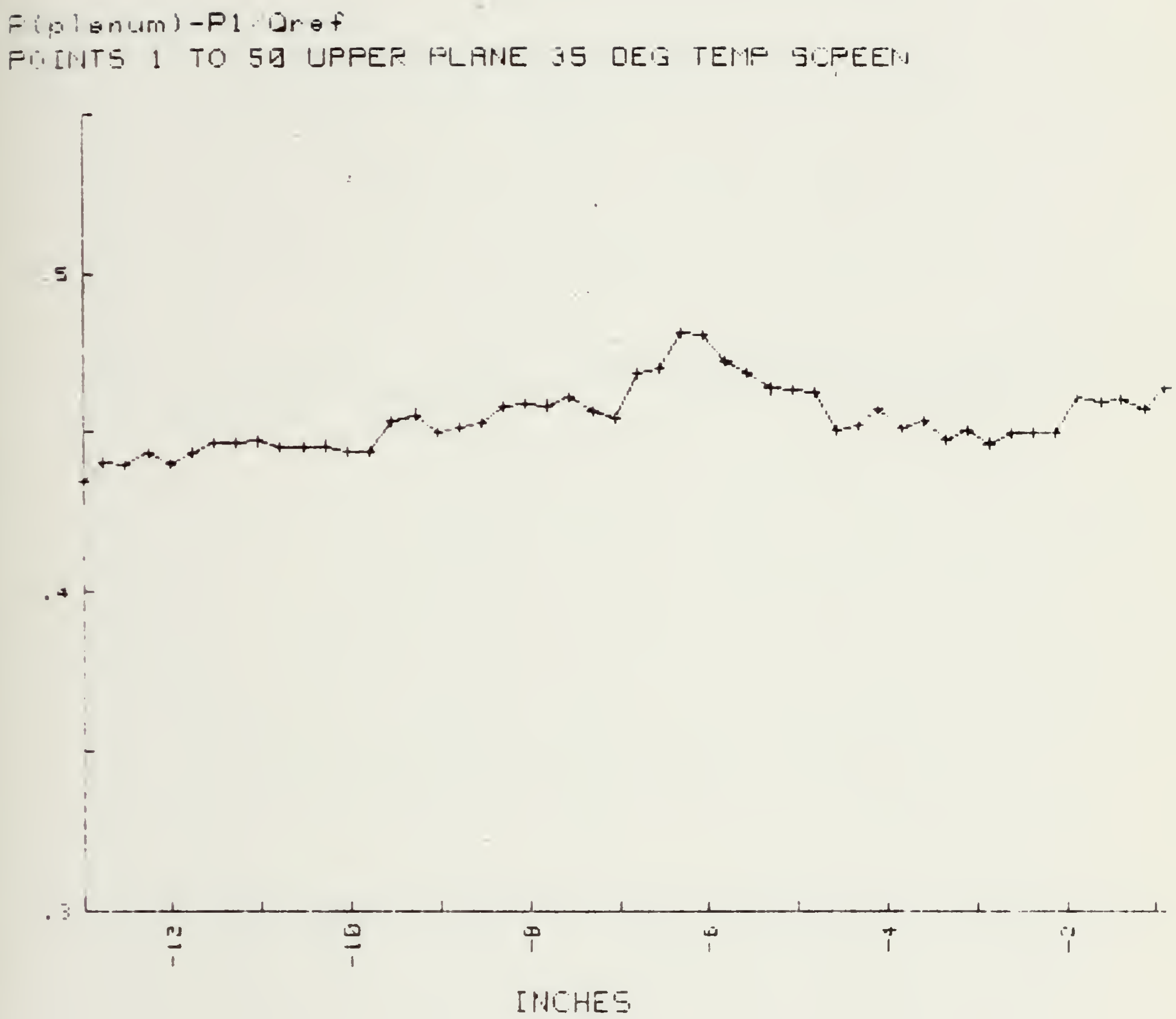


Fig. 36. Probe Survey Data at Midspan, Upper Plane 16 Mesh Screen, Walls at 35°, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

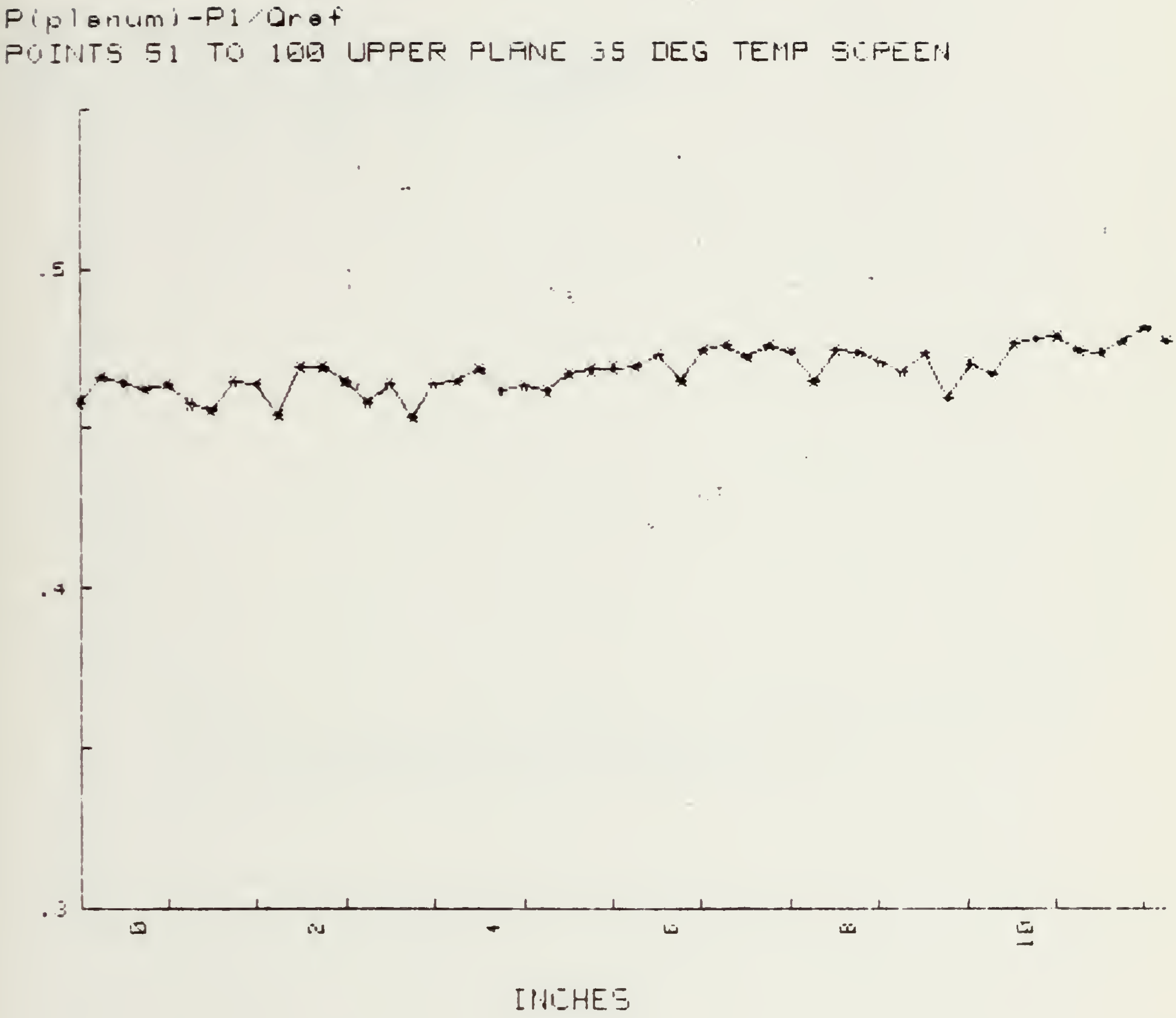


Fig. 37. Probe Survey Data at Midspan, Upper Plane
16 Mesh Screen, Walls at 35°, Points 51 to 100
$(P_{PLENUM} - P_t)/Q_{ref}$

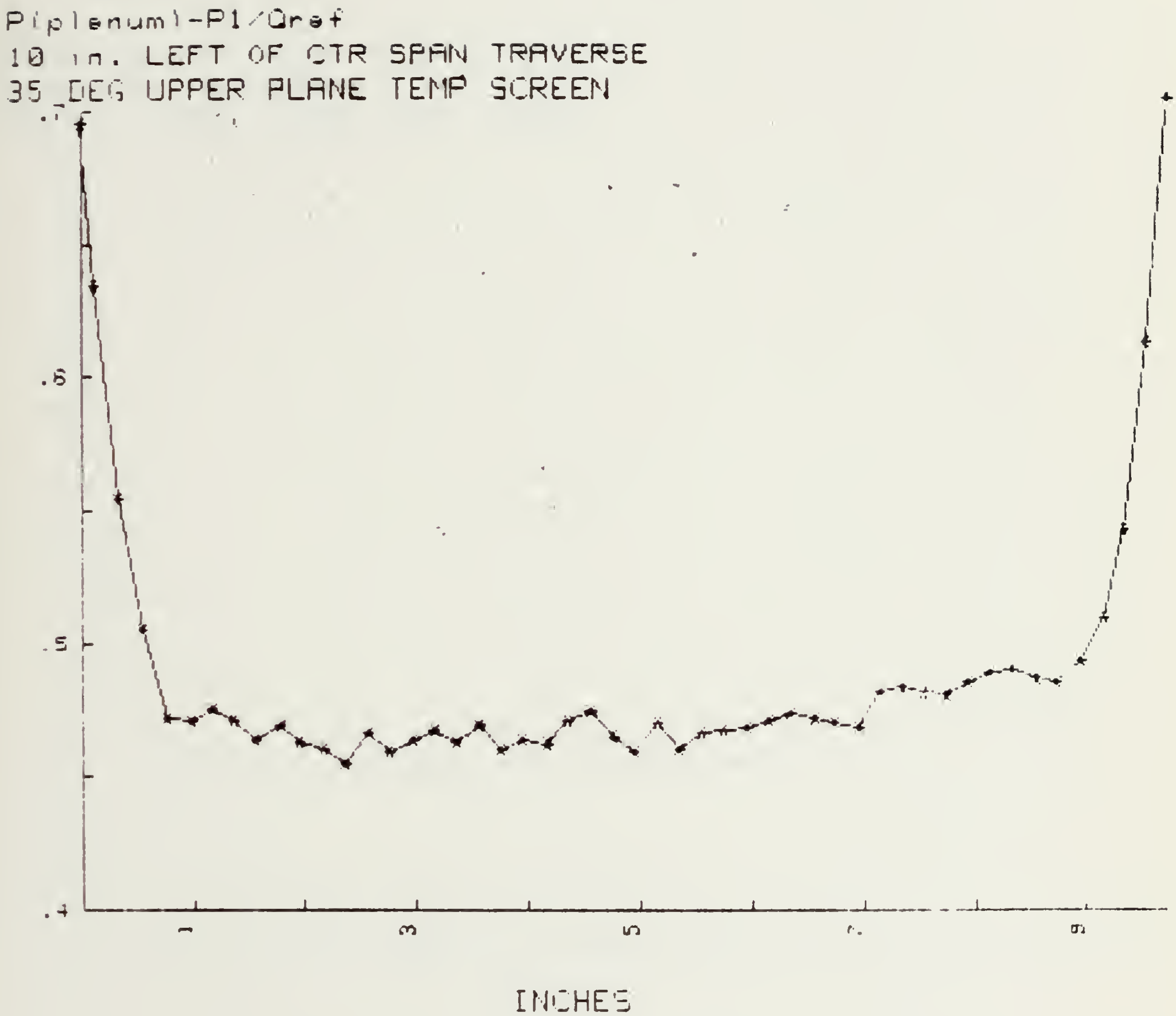


Fig. 38. Probe Survey Data Span Traverse, Lower Plane 16 Mesh Screen, Walls at 35°, 10" Left of CTR $(P_{PLENUM} - P_t)/Q_{ref}$

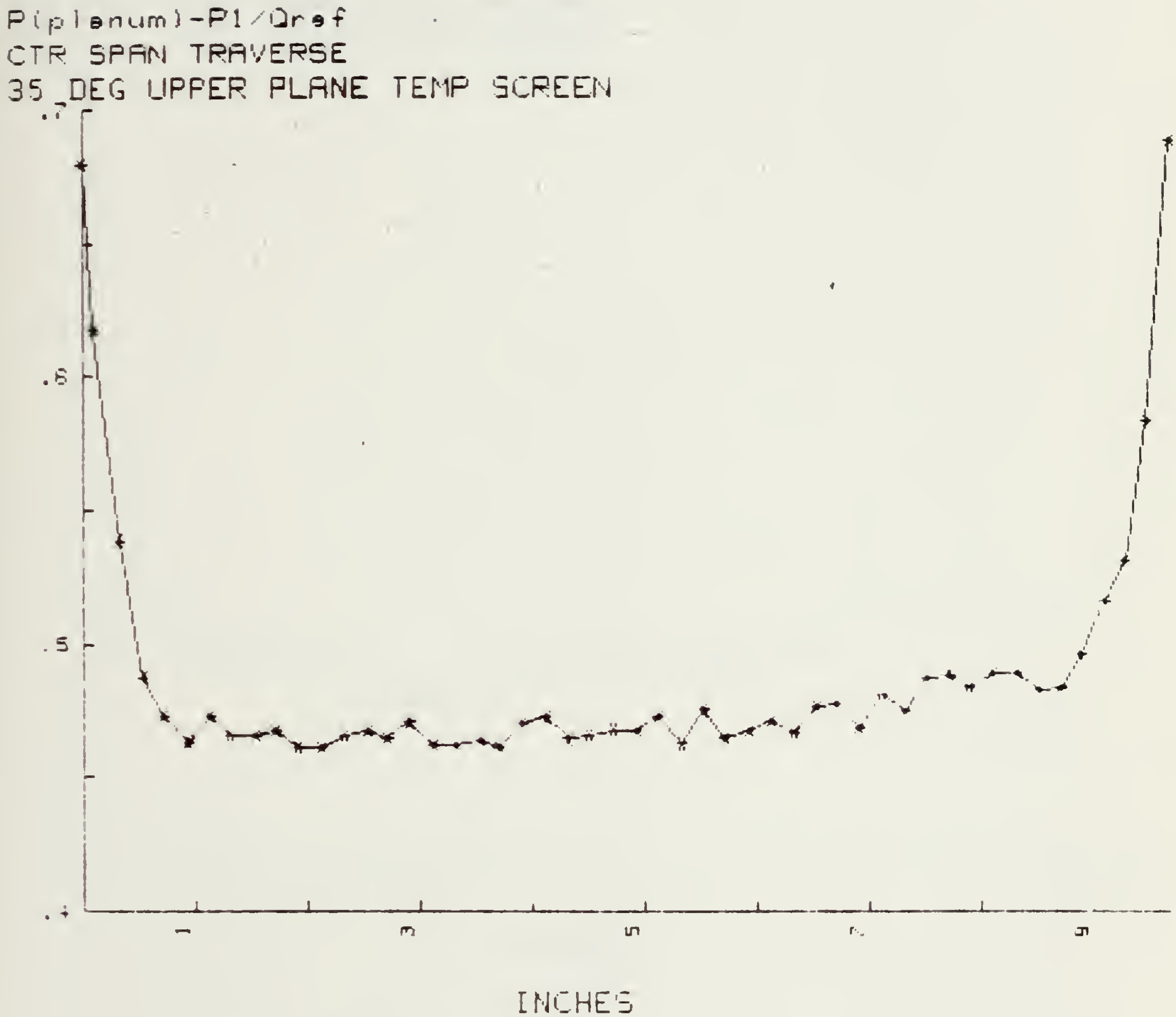


Fig. 39. Probe Survey Data Span Traverse, Lower Plane 16 Mesh Screen, Walls at 35°, Center of Test Section $(P_{PLENUM} - P_t)/Q_{ref}$

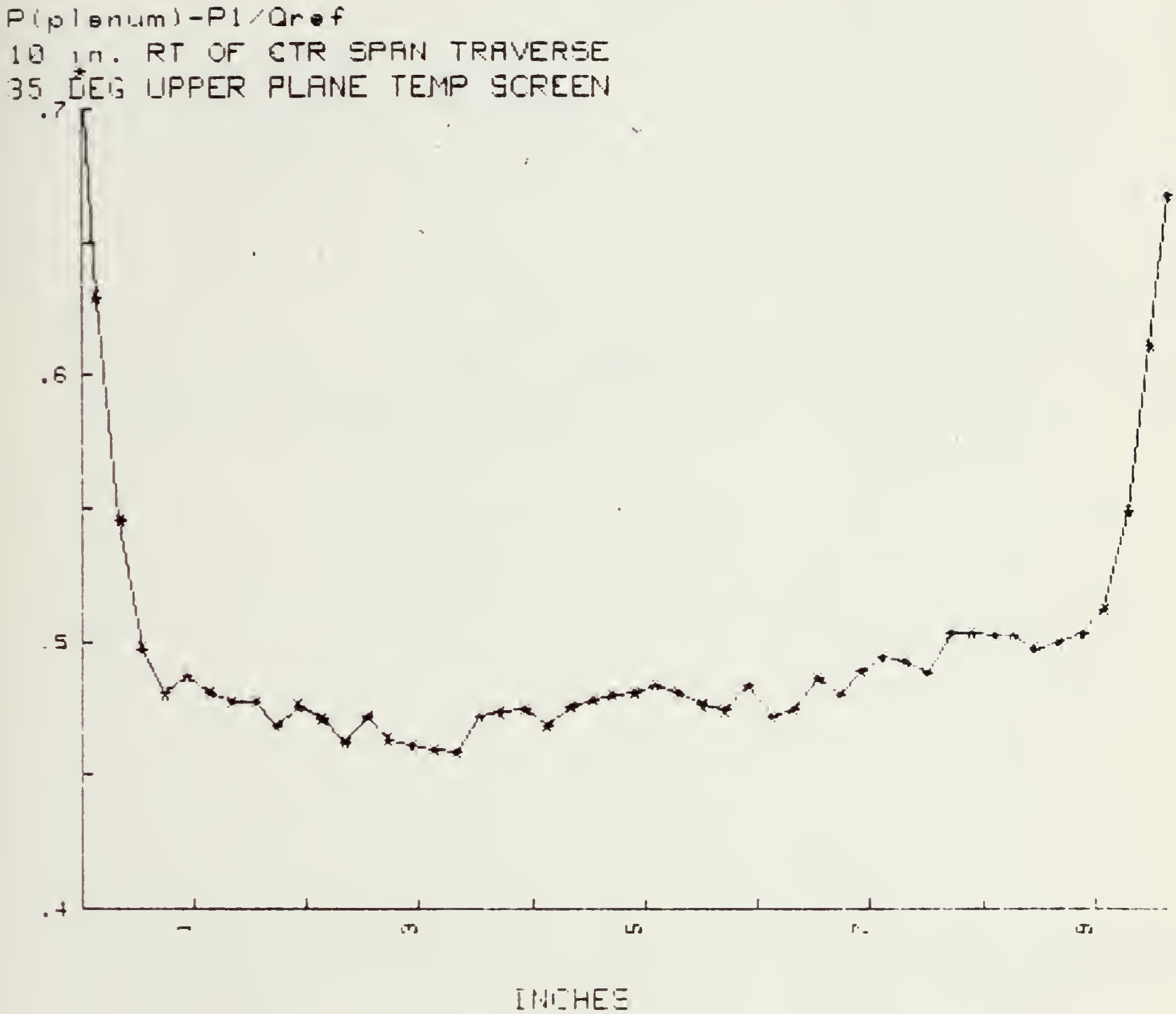


Fig. 40. Probe Survey Data Span Traverse, Lower Plane 16 Mesh Screen, Walls at 35°, Center of Test Section $(P_{PLENUM} - P_t)/Q_{ref}$

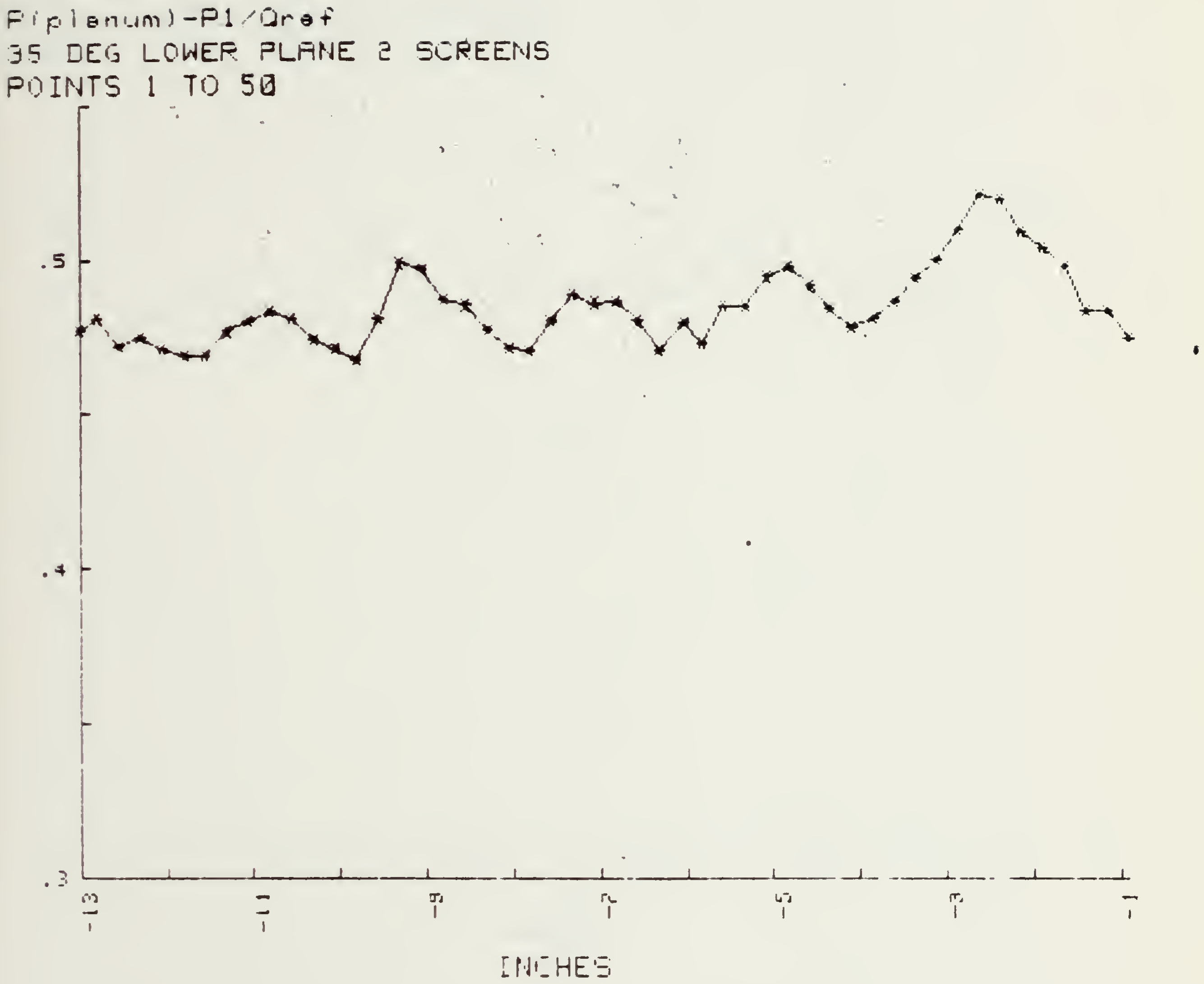


Fig. 41. Probe Survey Data at Midspan, Lower Plane 16 Mesh and 2 Mesh, Walls at 35°, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

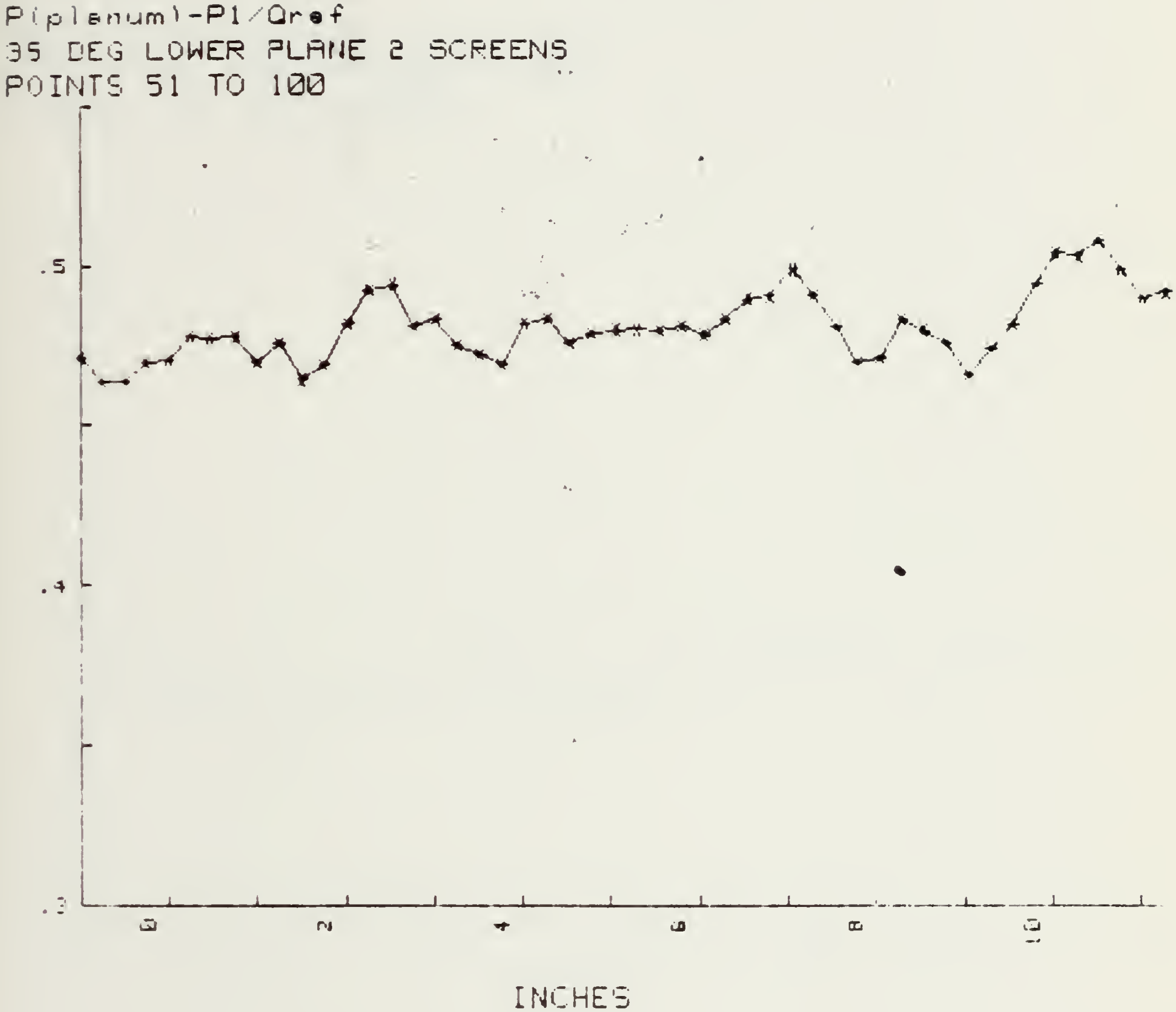


Fig. 42. Probe Survey Data at Midspan, Lower Plane 16 Mesh and 2 Mesh, Walls at 35°, Points 51 to 100 $(P_{PLENUM} - P_t)/Q_{ref}$

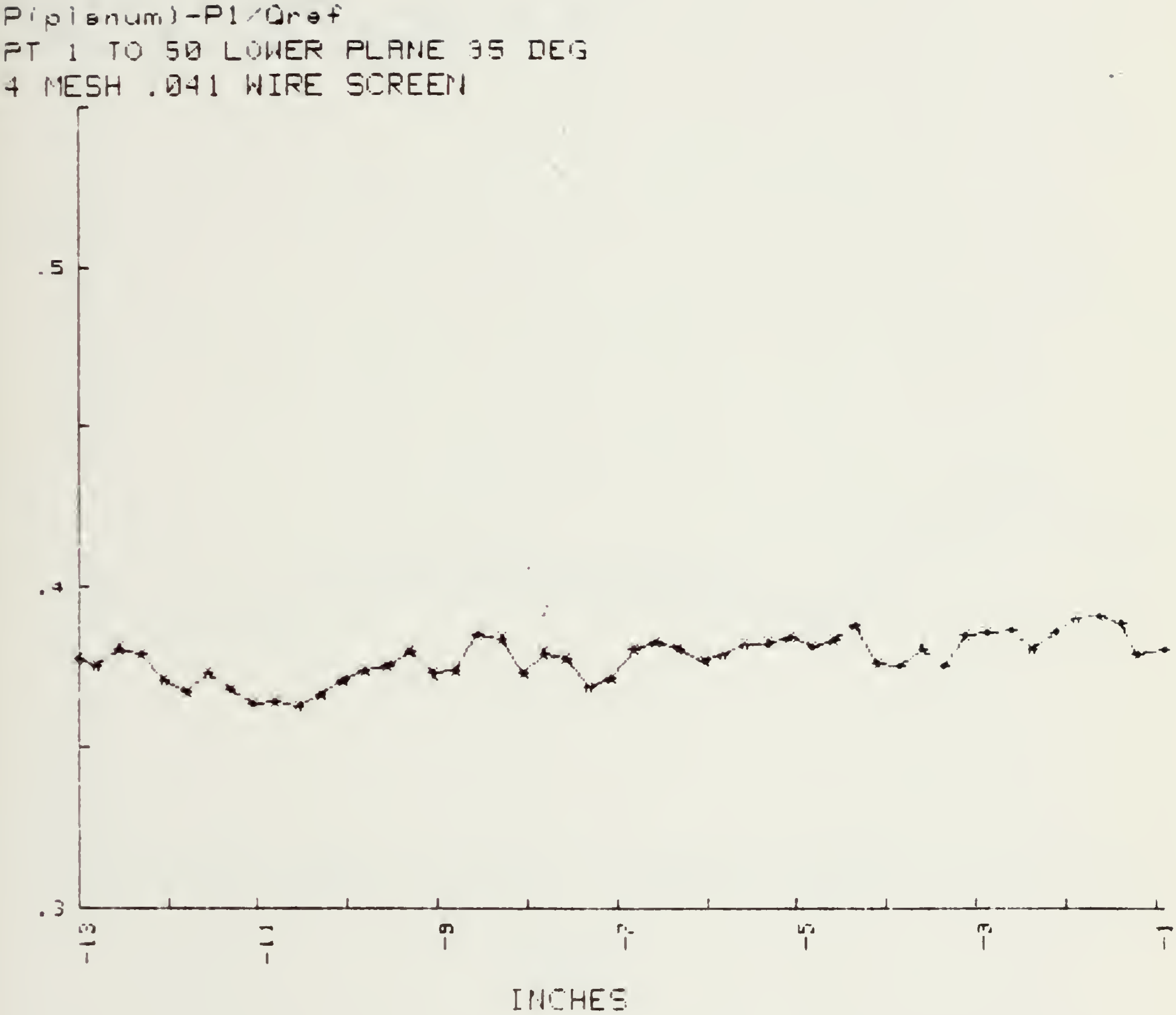


Fig. 43. Probe Survey Data at Midspan, Lower Plane
4 Mesh Screen, Walls at 35°, Points 1 to 50
$(P_{PLENUM} - P_t)/Q_{ref}$

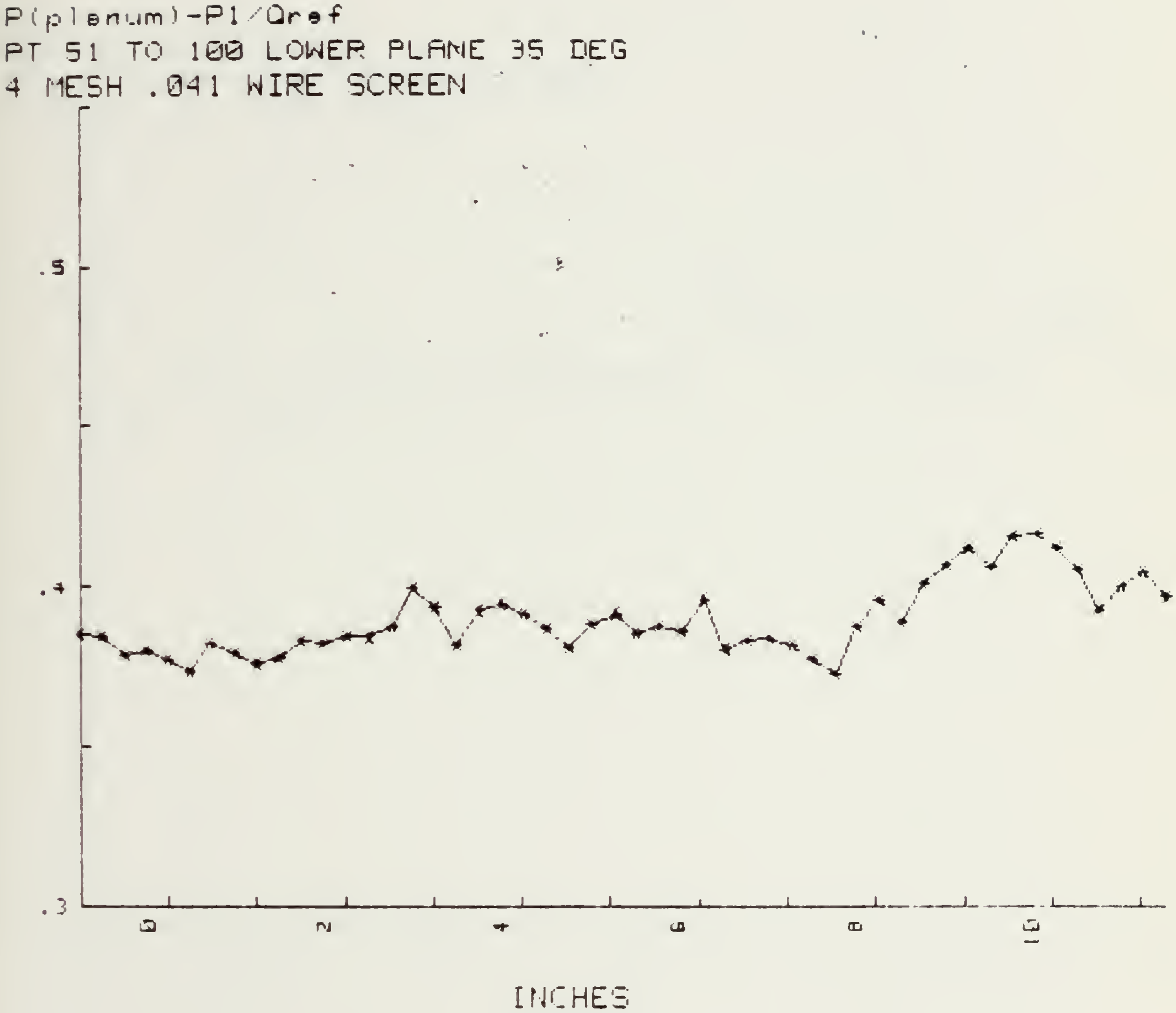


Fig. 44. Probe Survey Data at Midspan, Lower Plane 4 Mesh Screen, Walls at 35°, Points 51 to 100 $(P_{PLENUM} - P_t)/Q_{ref}$

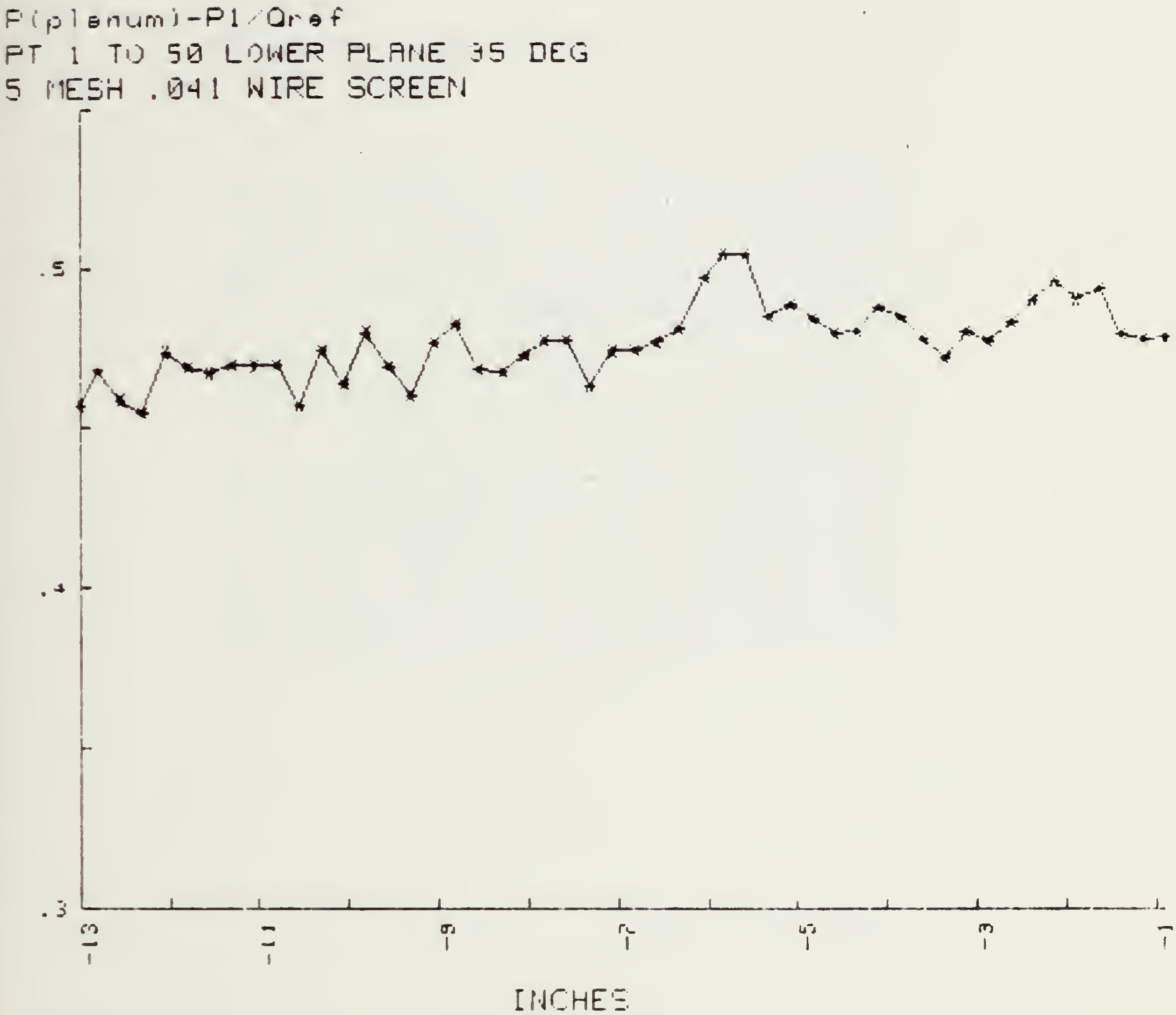


Fig. 45. Probe Survey Data at Midspan, Lower Plane 5 Mesh Screen, Walls at 35°, Points 1 to 50 $(P_{PLENUM} - P_t)/Q_{ref}$

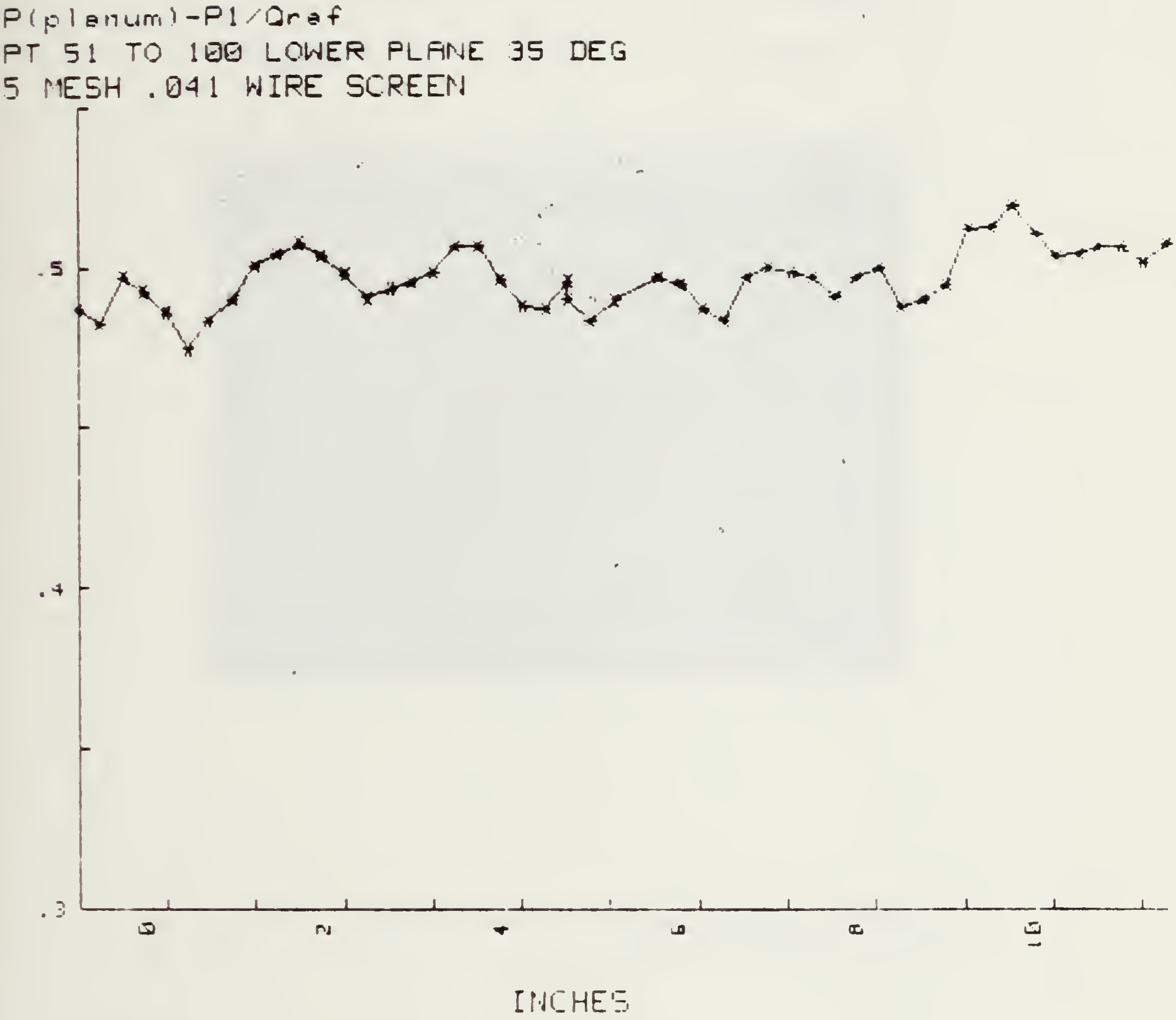


Fig. 46. Probe Survey Data at Midspan, Lower Plane 5 Mesh Screen, Walls at 35°, Points 51 to 100 $(P_{PLENUM} - P_t)/Q_{ref}$

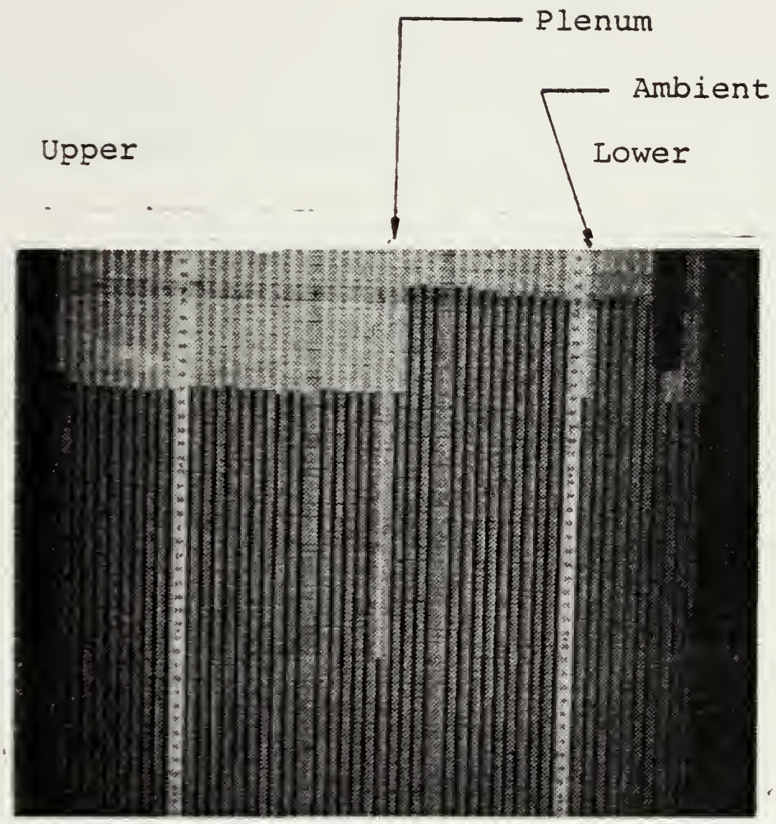


Fig. 47. Wall Static Pressure Distribution

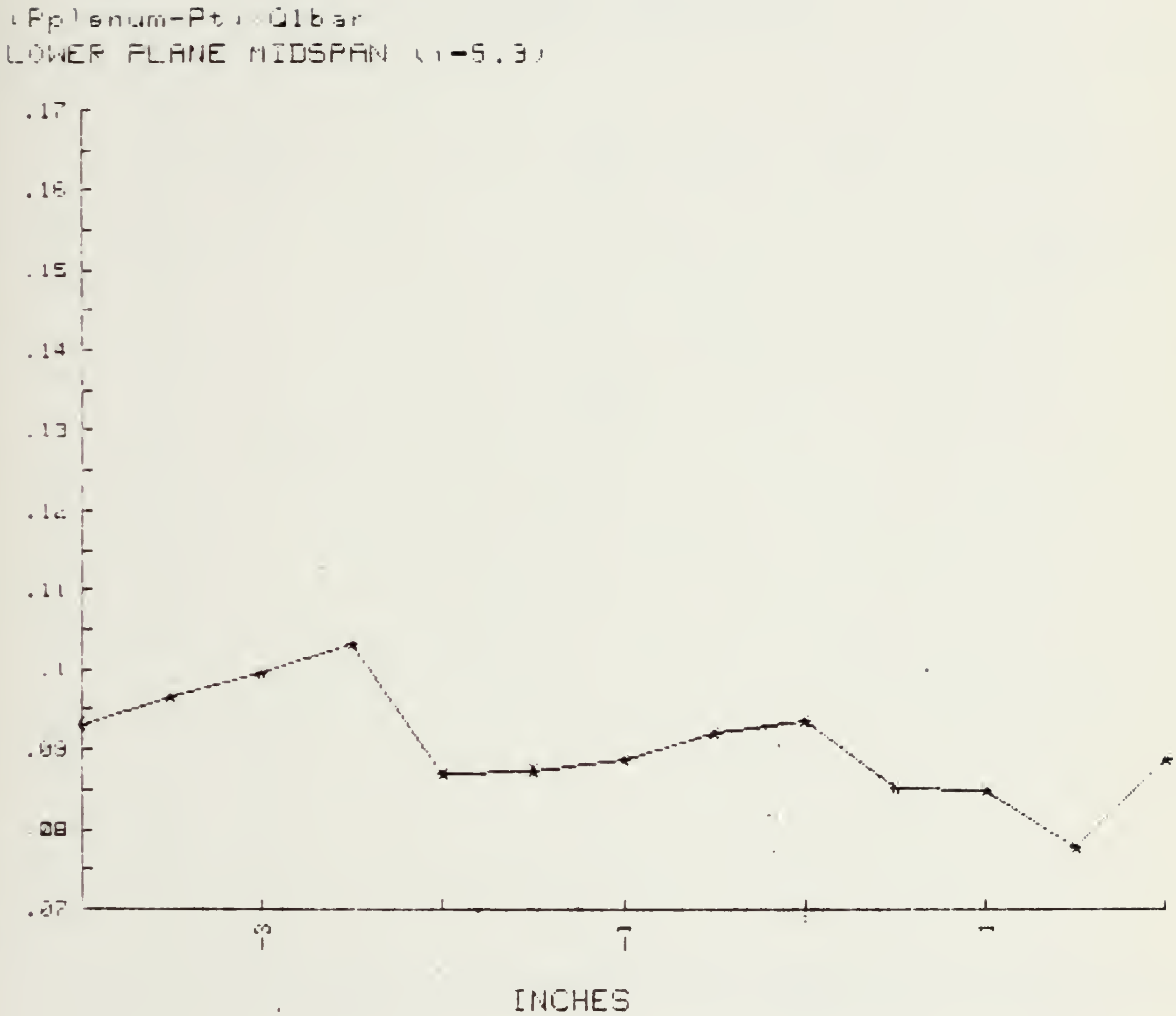
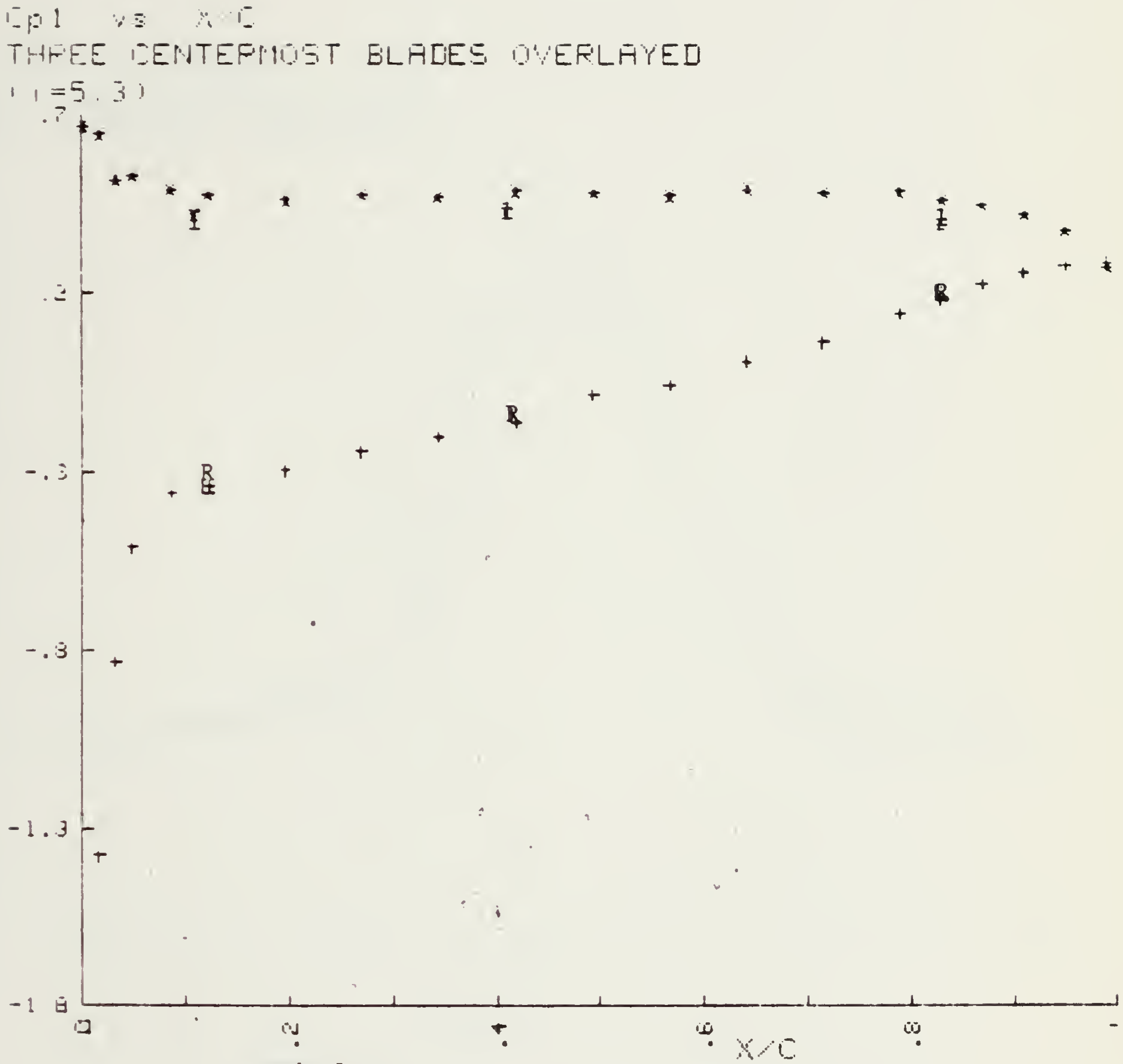


Fig. 48. Probe Survey Data at Upstream Midspan (i = 5.3, $(P_{PLENUM} - P_t)/\bar{Q}_1$, Lower Plane)



Symbols:

BLADE	LEFT	CENTER	RIGHT
Pressure Side	l	*	r
Suction Side	L	+	R

Fig. 49. Blade Surface Pressure Distribution on Three Centermost Blades (i = 5.3)

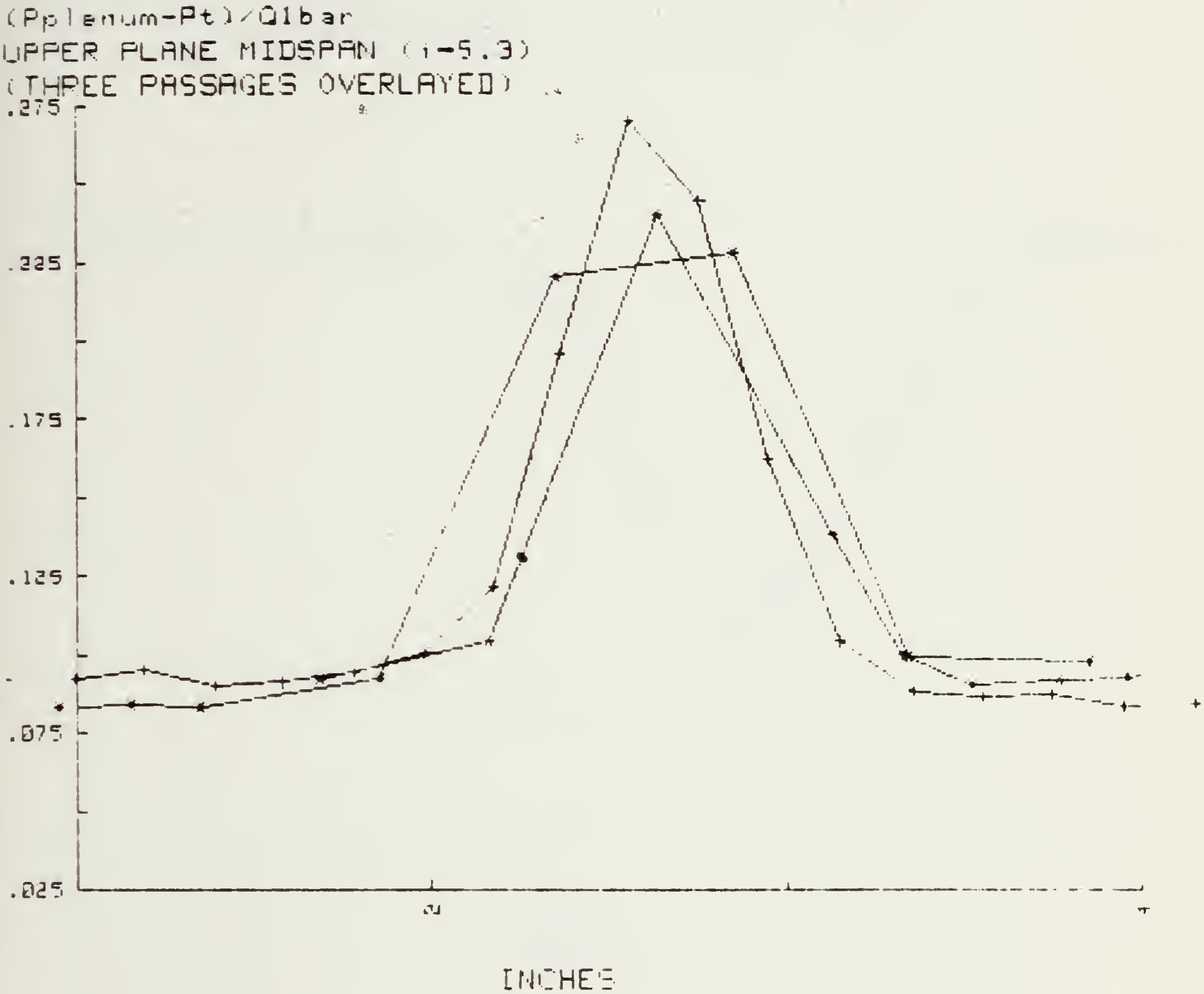


Fig. 50. Probe Survey Data at Midspan
(i = 5.3, $(P_{PLENUM} - P_t)/\bar{Q}_1$, Upper Plane)

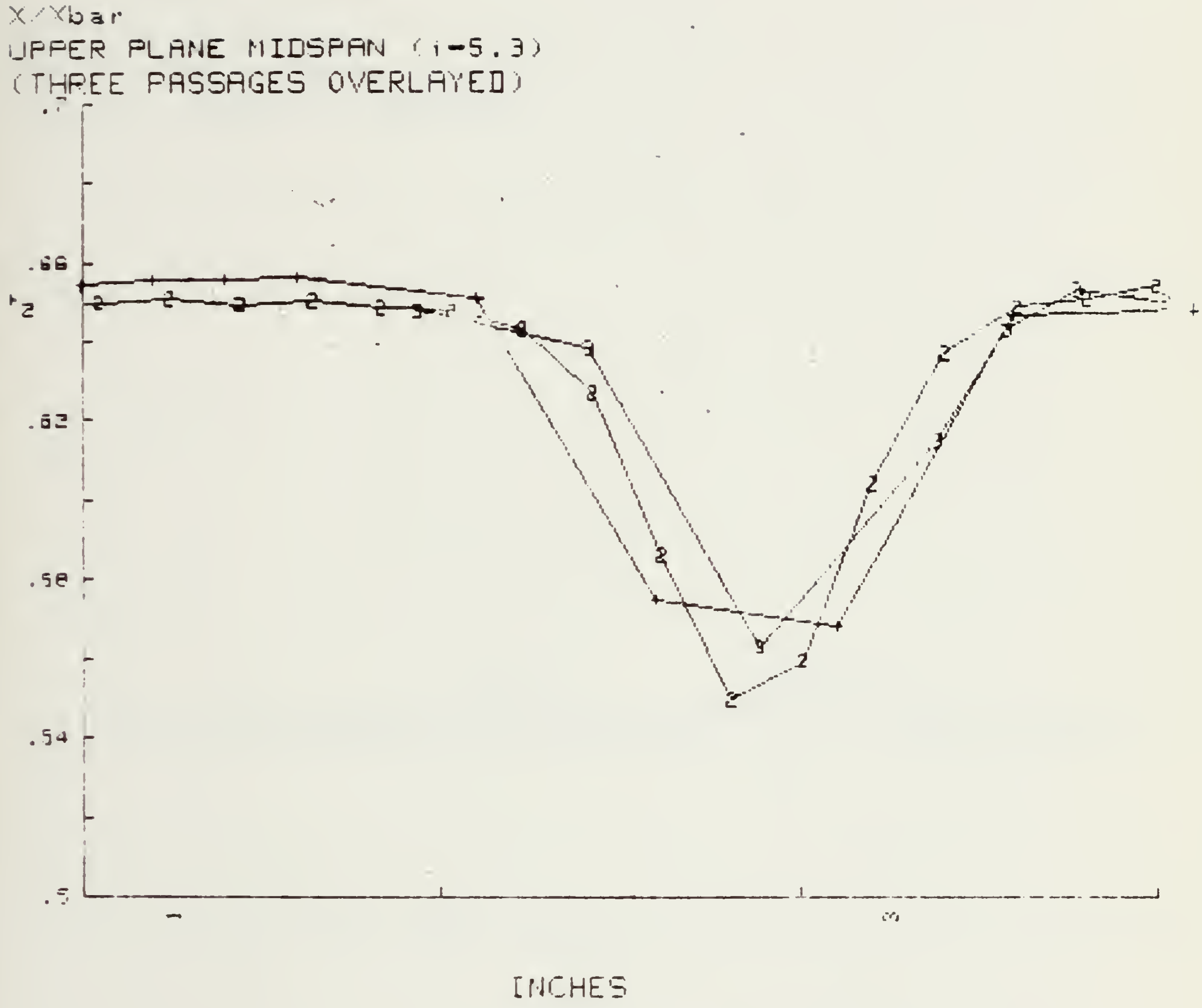


Fig. 51. Probe Survey Data at Midspan
(i = 5.3, $(X/\overline{X})$, Upper Plane)

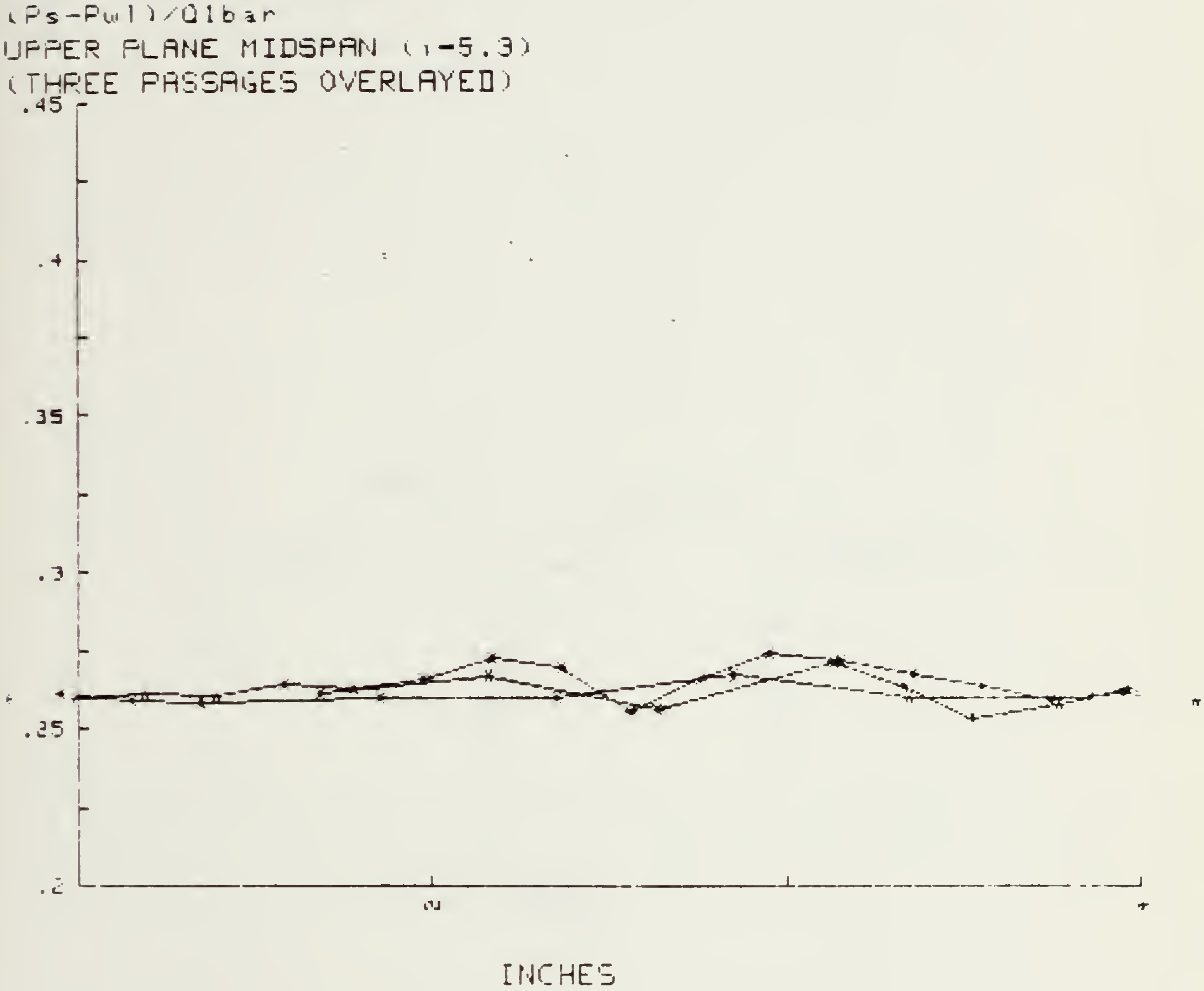


Fig. 52. Probe Survey Data at Midspan
(i = 5.3, $(P_s - P_{w1})/\bar{Q}_1$, Upper Plane)

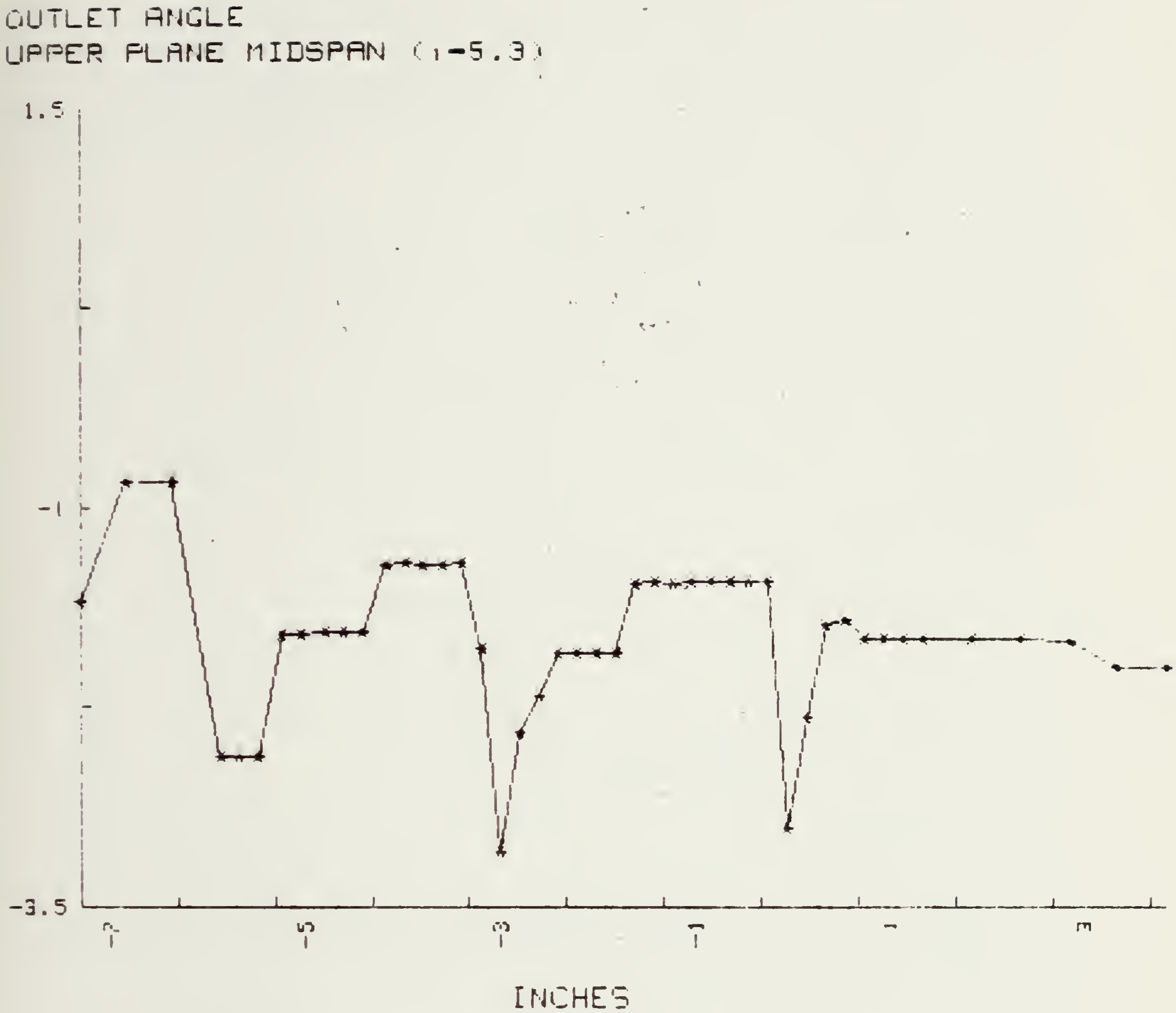


Fig. 53. Probe Survey Data at Midspan
(i = 5.3, Outlet Angle, Upper Plane)

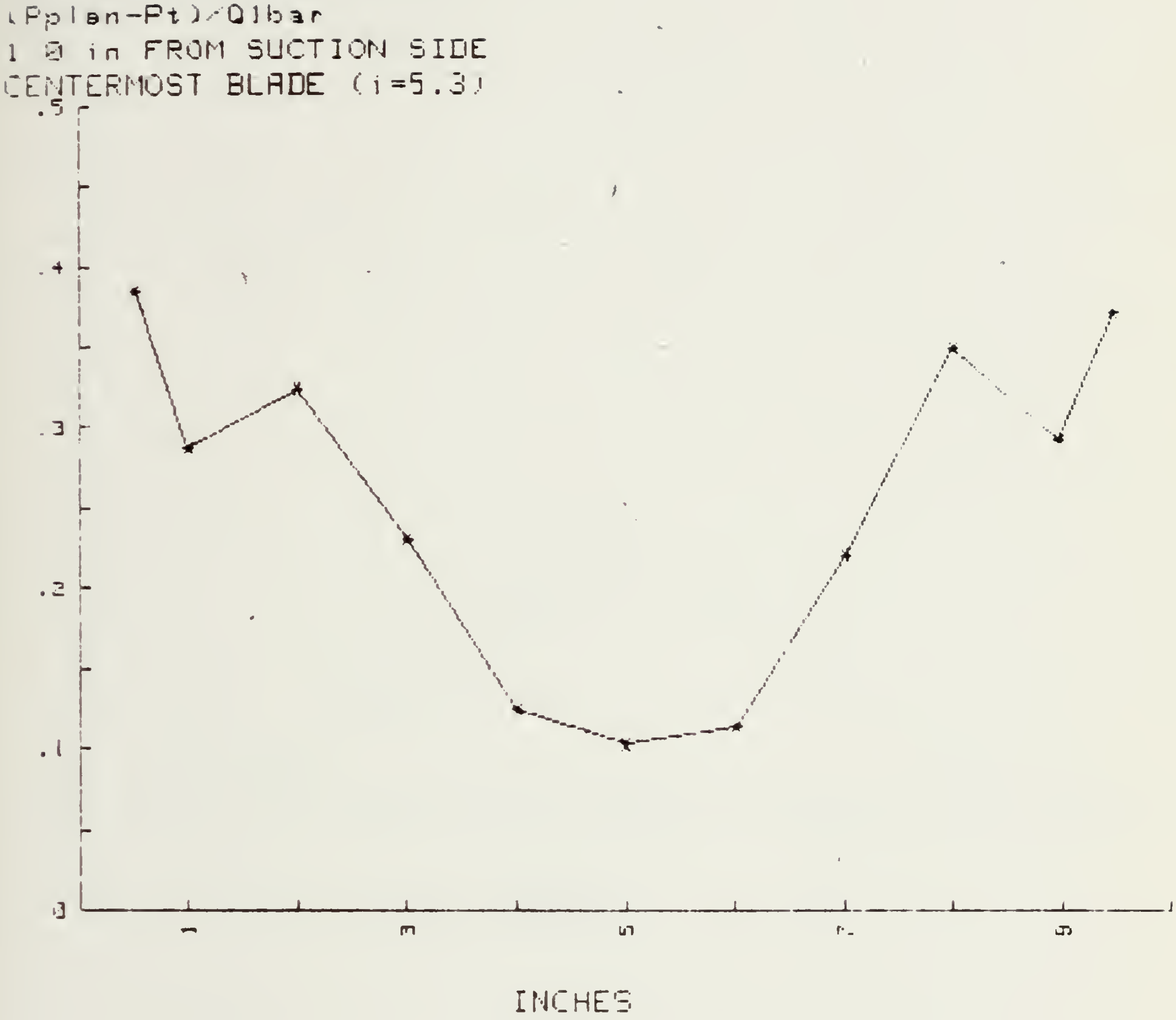


Fig. 54. Spanwise Probe Data Surveyed 1 in. from Suction Side of Centermost Blade (i = 5.3, $(P_{PLENUM} - P_t)/\bar{Q}_1$, Upper Plane)

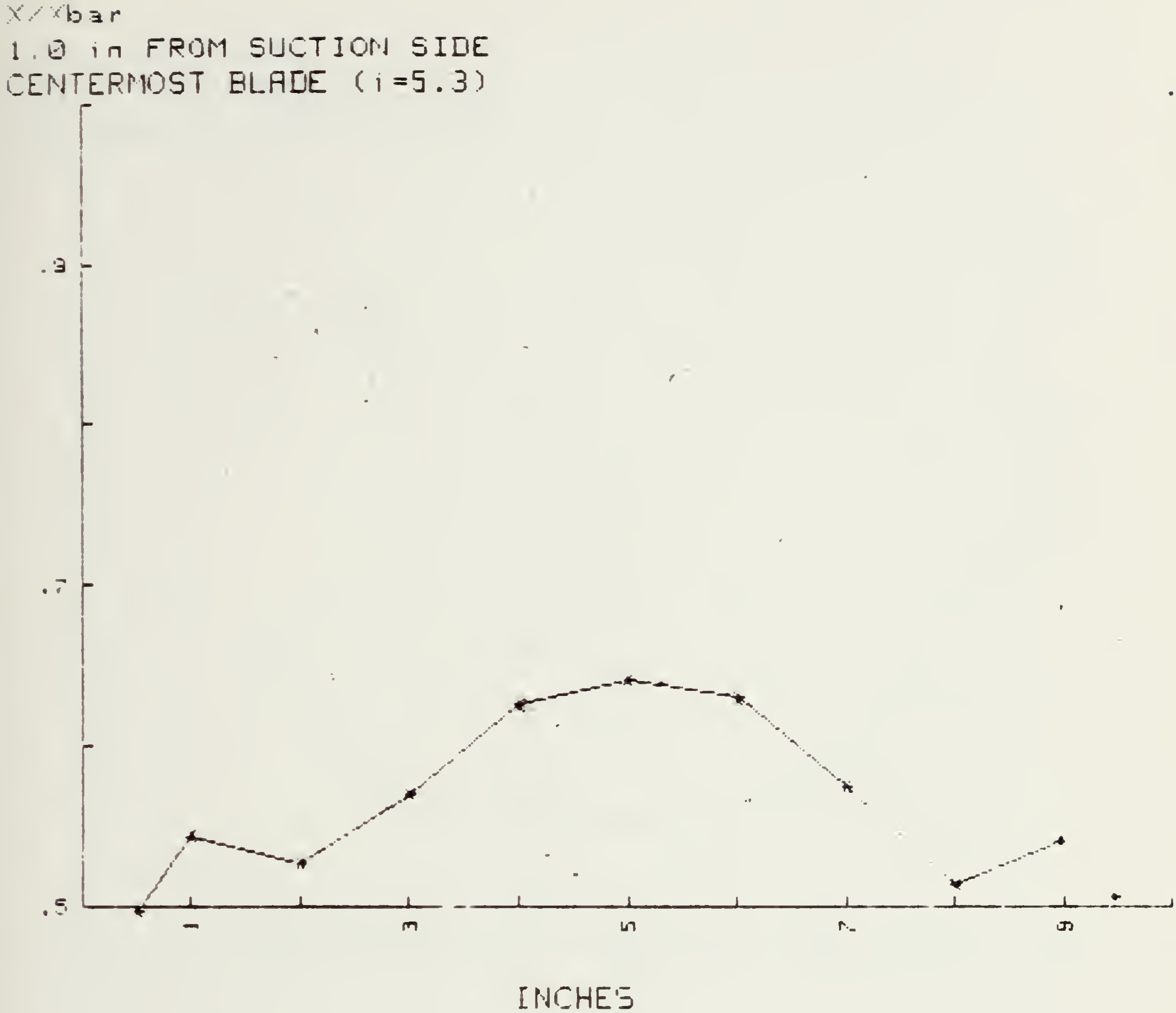


Fig. 55. Spanwise Probe Data Surveyed 1 in. from Suction Side of Centermost Blade (i = 5.3, $X/\overline{X}$, Upper Plane)

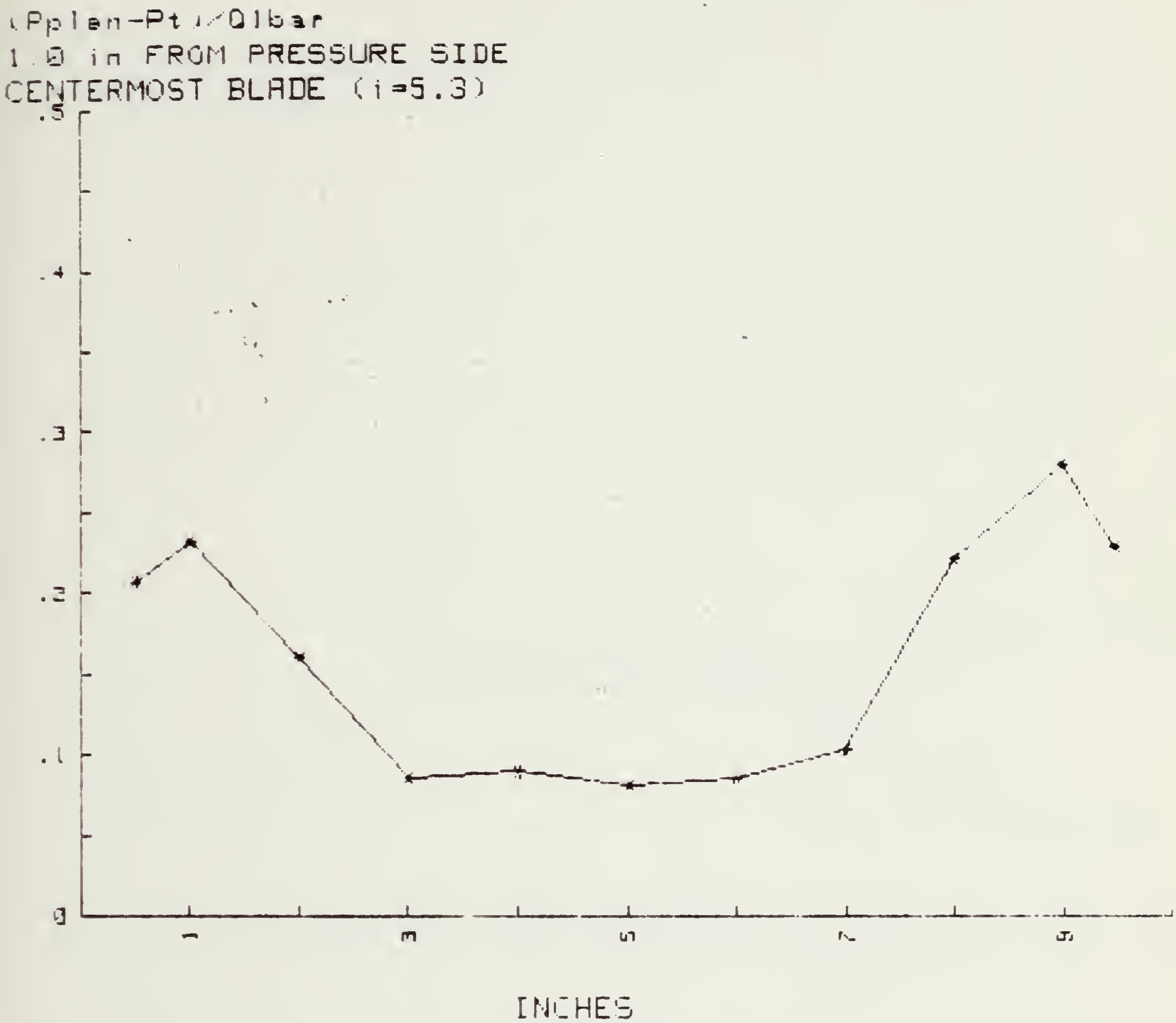


Fig. 56. Spanwise Probe Data Surveyed 1 in. from Pressure Side of Centermost Blade (i = 5.3, $(P_{PLENUM} - P_t)/\overline{Q}_1$, Upper Plane)

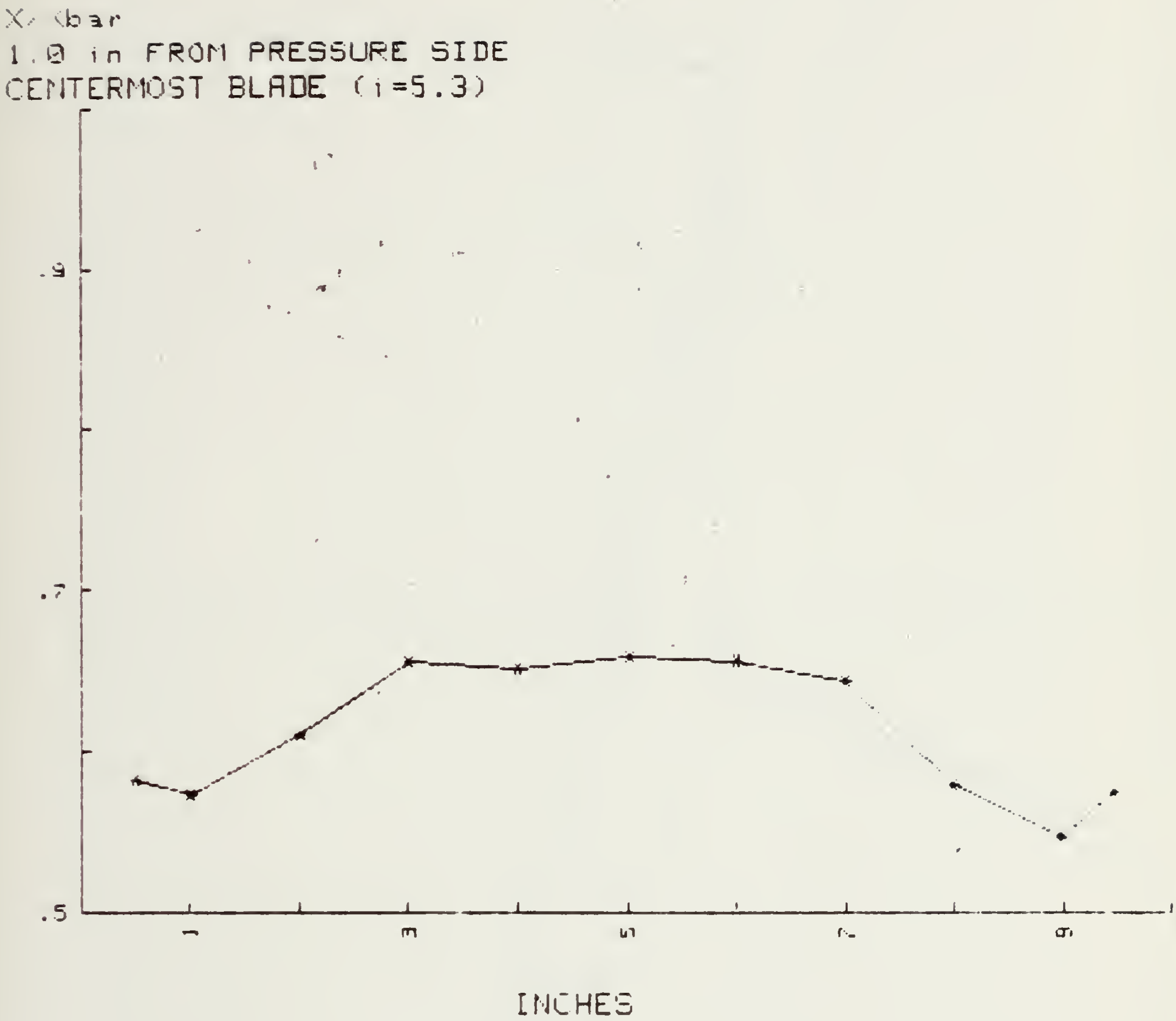


Fig. 57. Spanwise Probe Data Surveyed 1 in. from Pressure Side of Centermost Blade (i = 5.3, $X/\overline{X}$, Upper Plane)

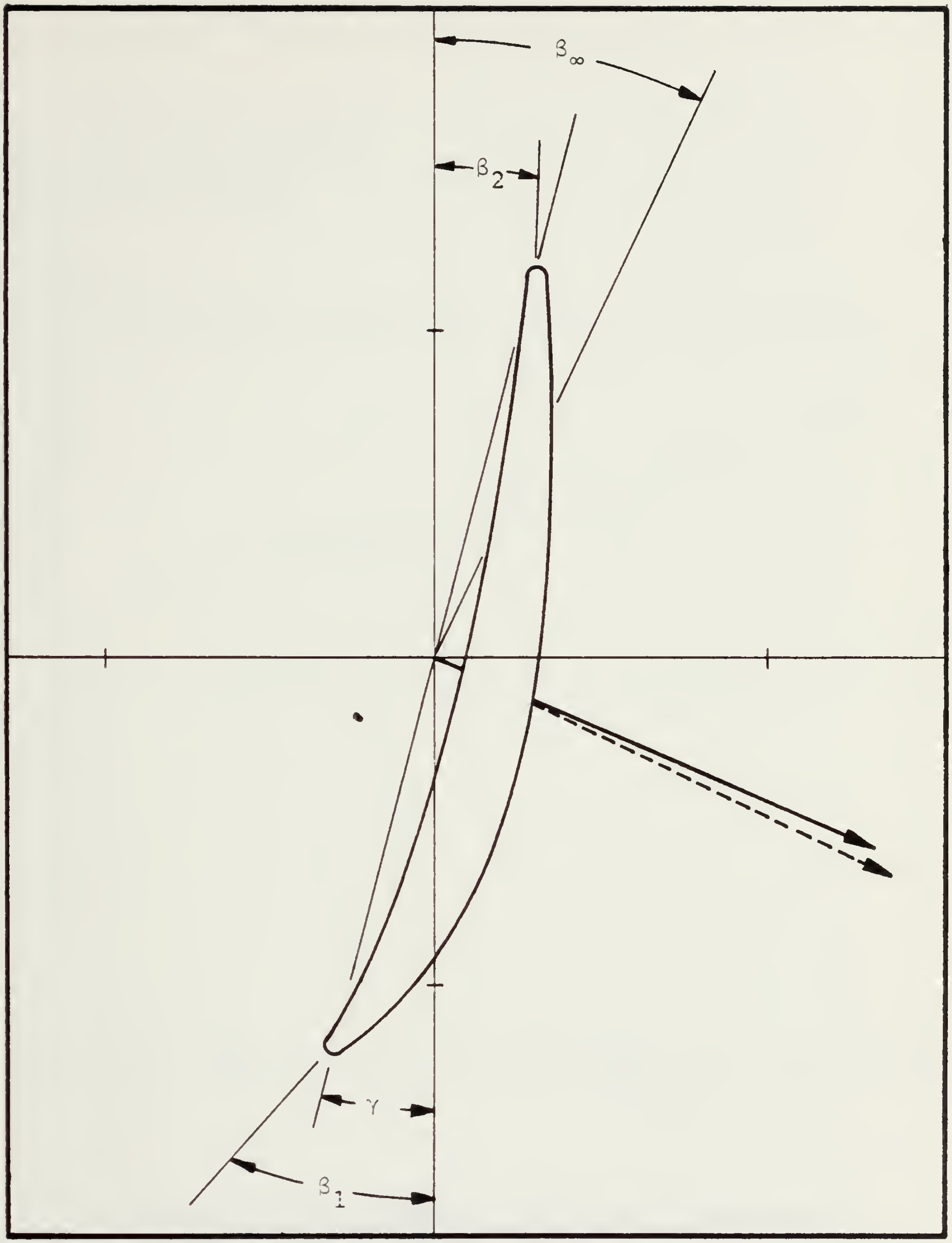


Fig. 58. Resultant Blade Force Vectors by Momentum Balance (– – – – –) and from Surface Pressure Integration (————) $i = 5.3$

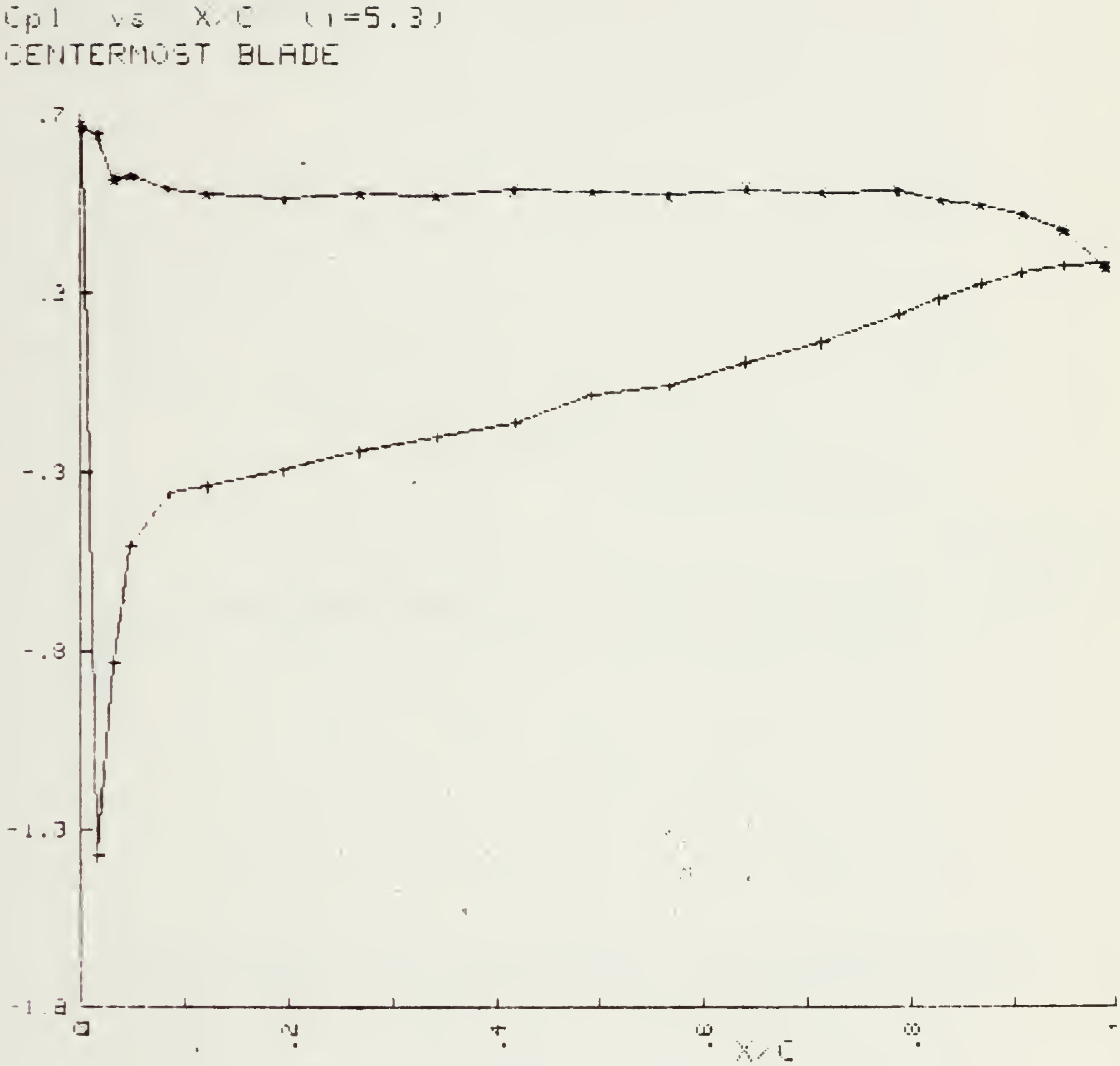


Fig. 59. Measured Blade Surface Pressure Distribution
(i = 5.3, * = Pressure Side,
+ = Suction Side)

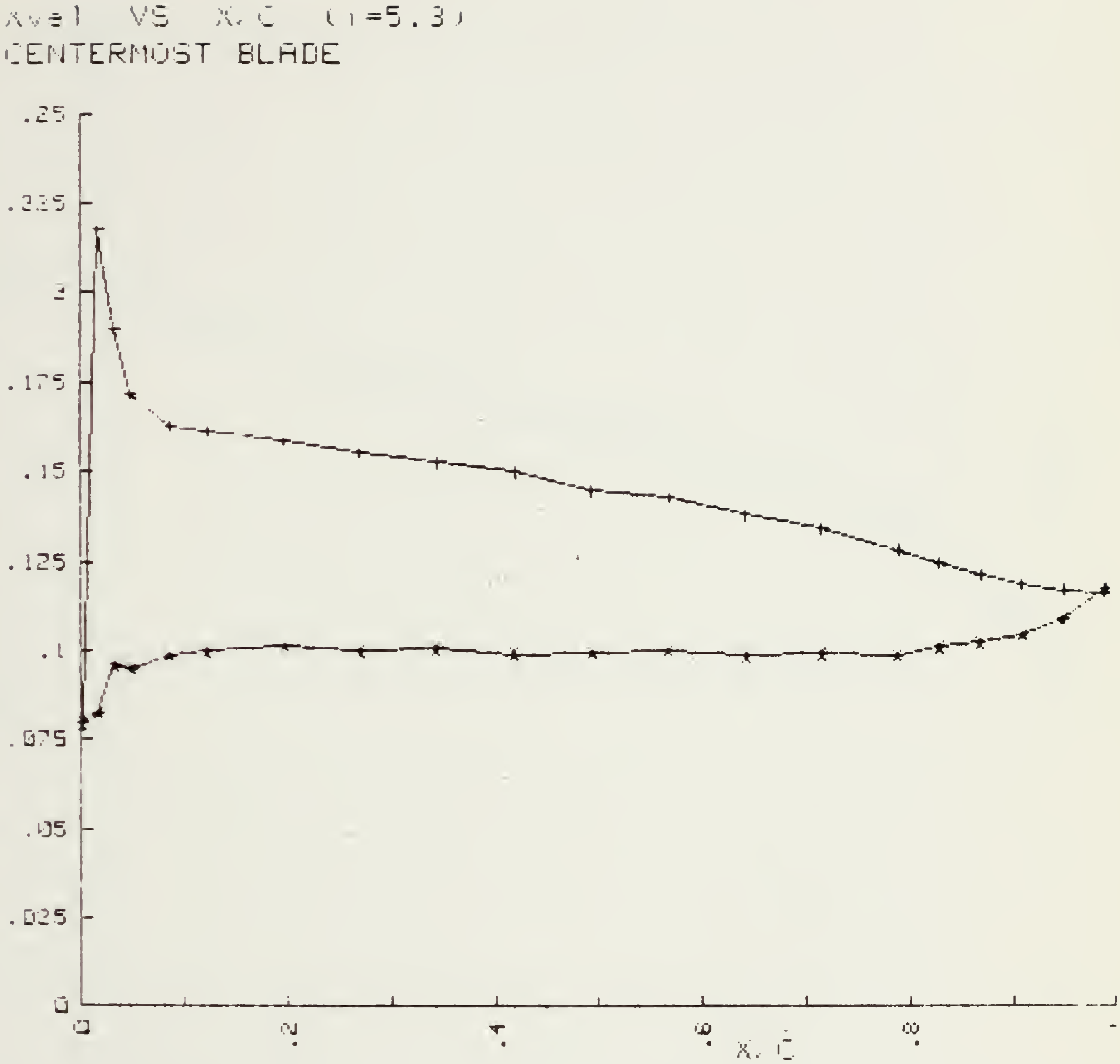


Fig. 60. Measured Blade Surface Velocity Distribution
(i = 5.3, * = Pressure Side,
+ = Suction Side)

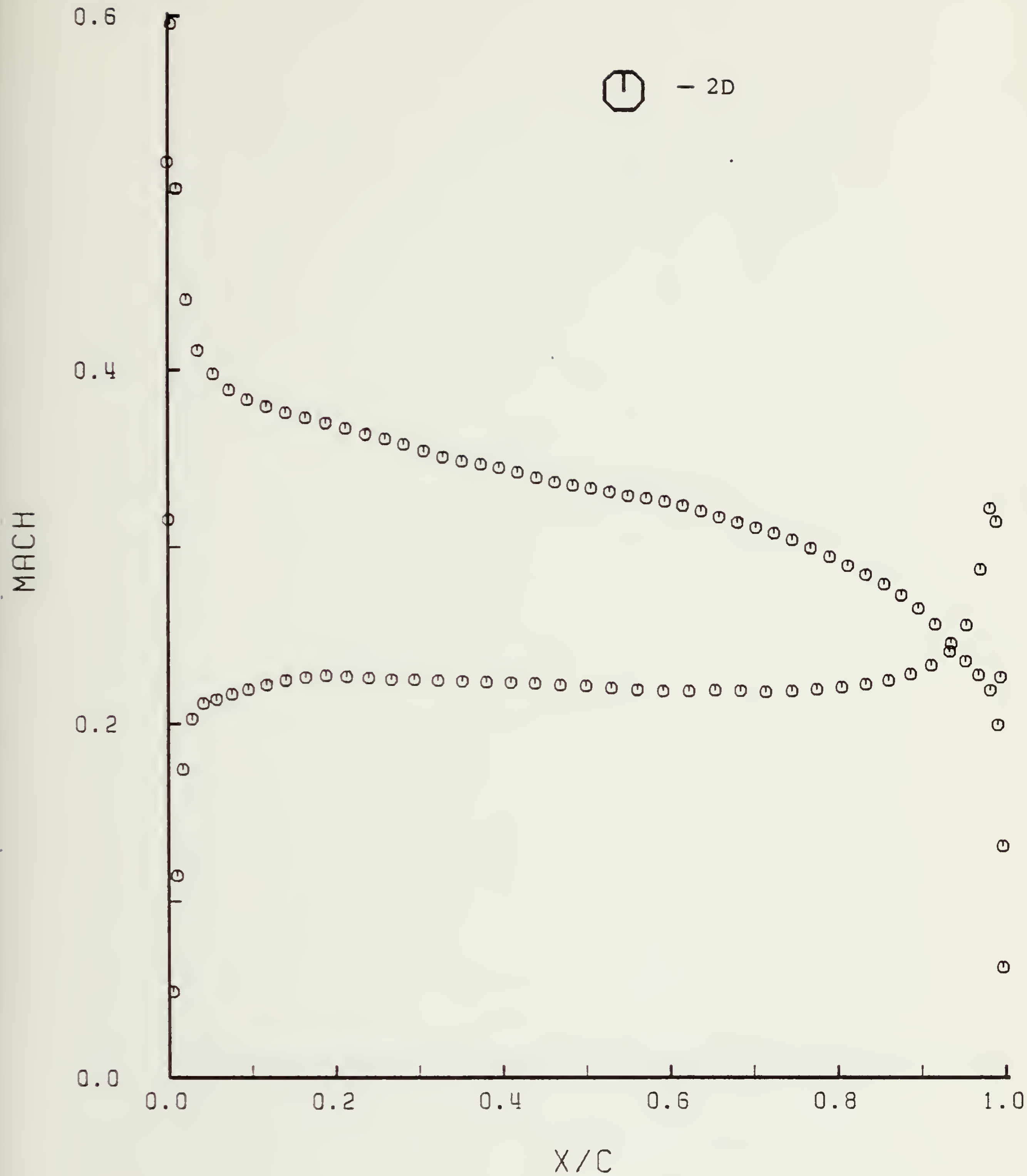


Fig. 61. 2D Code Blade Surface Mach Number Distribution (i = 5.3)

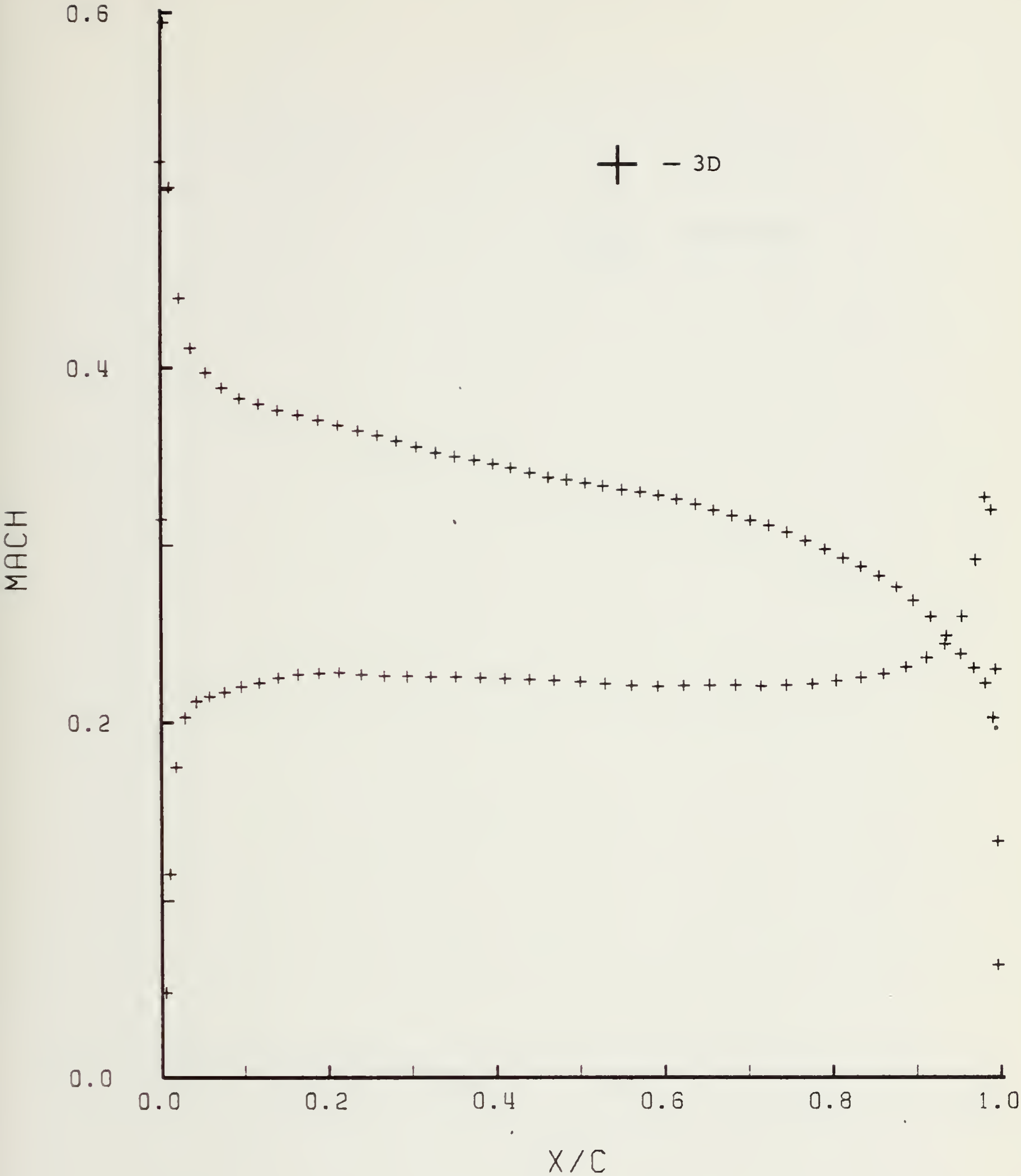


Fig. 62. 3D Code Blade Surface Mach Number Distribution (i = 5.3)

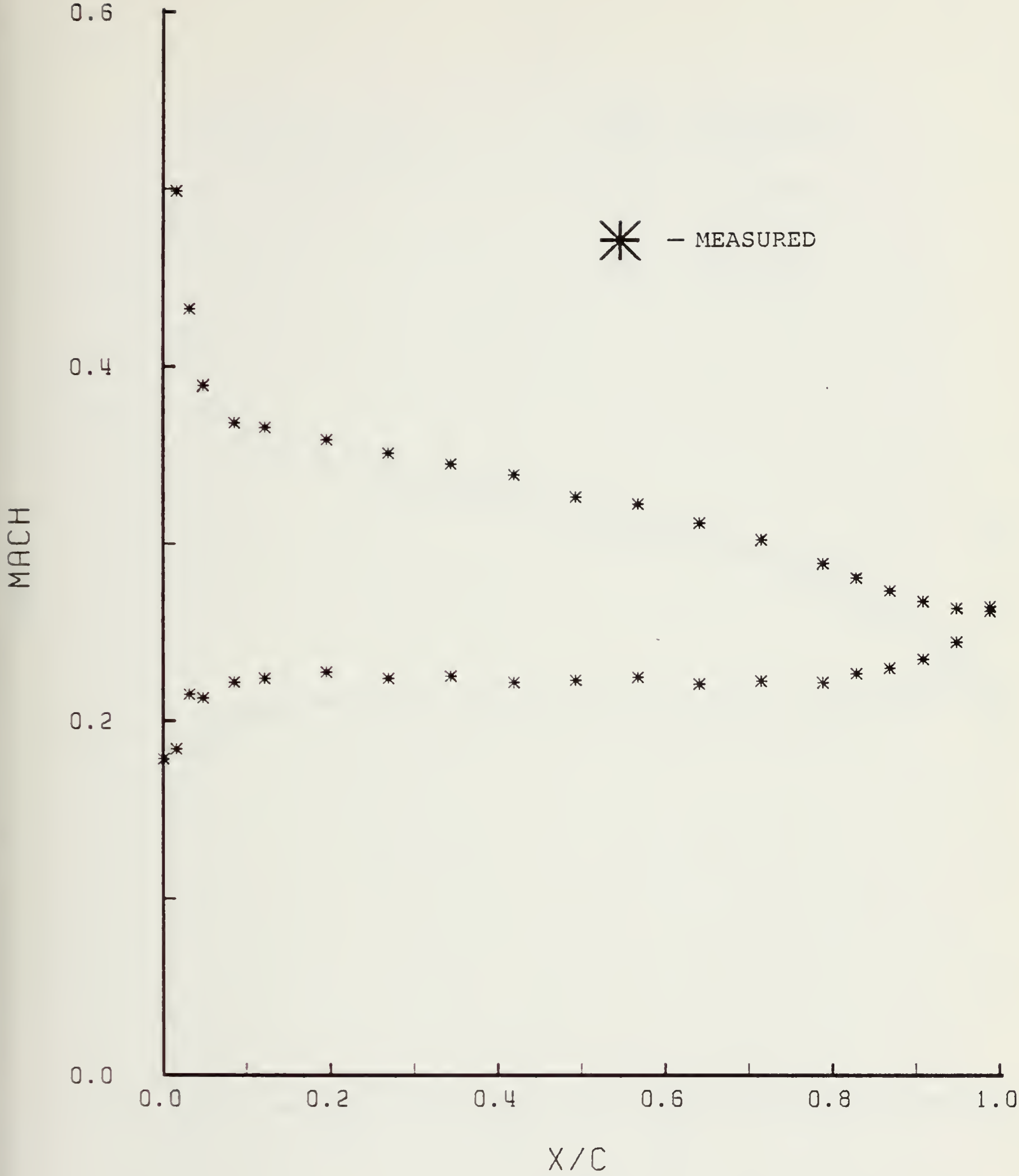


Fig. 63. Measured Blade Surface Mach Number Distribution (i = 5.3)

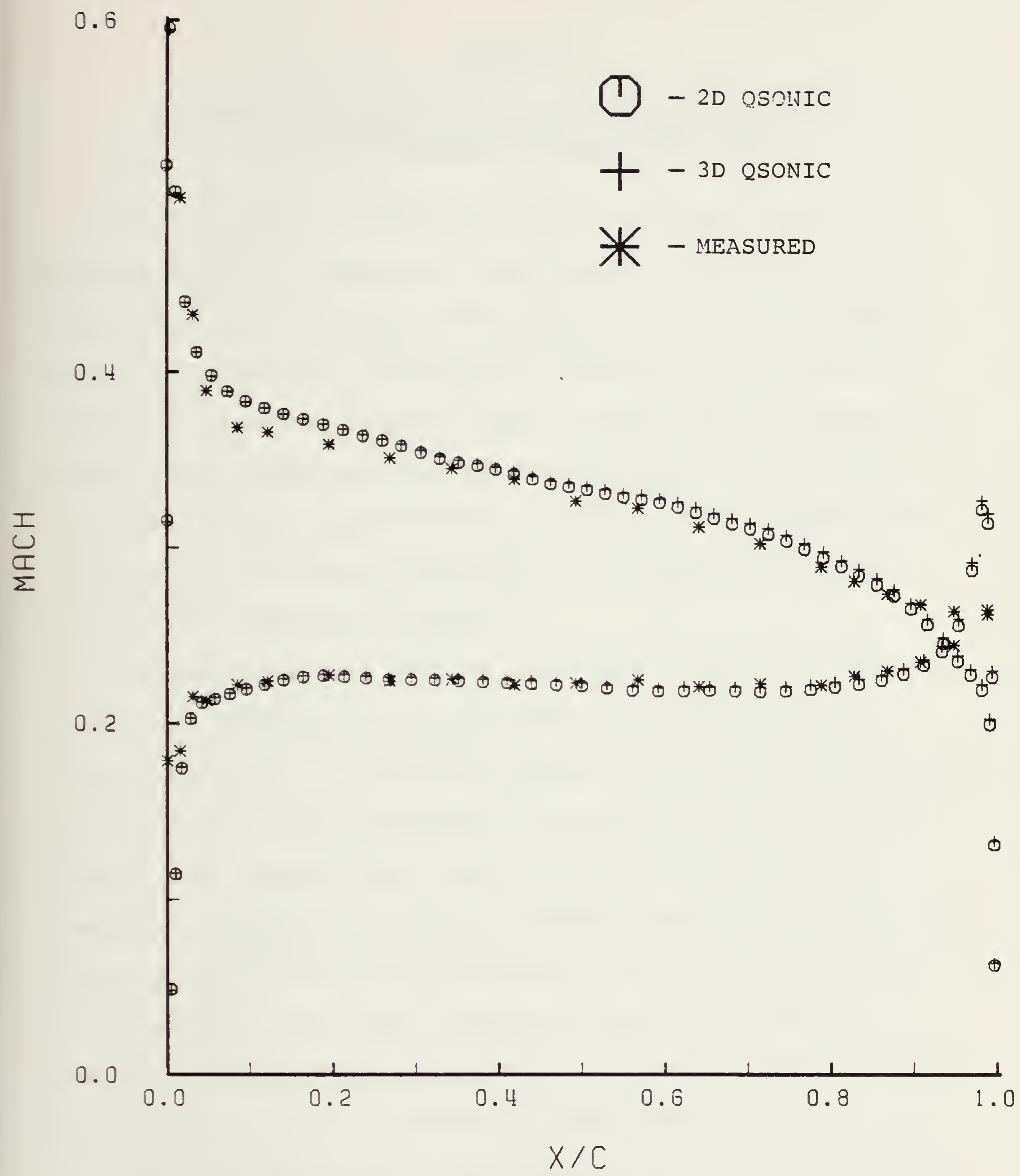


Fig. 64. Blade Surface Mach Number Distribution (i = 5.3)

APPENDIX A

MODIFICATION TO THE INLET GUIDE VANE SECTION OF THE SUBSONIC CASCADE WIND TUNNEL

As discussed in Section I, Cina discovered during his test program that while the inlet flow to the test section was uniform in direction and uniform in wall static pressure, it contained a variation in velocity and stagnation pressure resulting from the wakes of the IGV's. Because the inlet guide vanes were spaced at intervals of two inches and the test cascade blades spaced at three inches, departures from strictly periodic conditions were detected from one test blade passage to another.

To alleviate this problem, the inlet guide vane arrangement was modified so that the guide vanes were placed at 1 inch intervals. In order to preserve the option of reverting to a two inch IGV arrangement and because it was not possible to machine the south wall to hold additional blades, a separate structure was placed between the bell mouth contraction and the walls of the cascade. By mounting the IGV's in a separate unit which remained fixed once installed, hardware adjustments between tests associated with a change of end wall angle were greatly simplified.

The new inlet guide vane assembly was constructed using two lengths of 10 inch steel channel as shown in Fig. A.1.

One set of guide vanes was mounted on the south side of the unit at 2 inch spacings. A second set of vanes was mounted at 2 inch spacings on the north side of the unit. When the unit was assembled the guide vanes mounted from alternate sides meshed, resulting in an inlet guide vane spacing of 1 inch. The unit was provided with a single hand crank at the east end so that the vanes would be adjusted in unison. Once installed the complete structure could be left in place when the cascade north wall was removed to adjust air inlet angle. The one inch vane spacing ensured that periodicity at the test section would result for any test blade spacing which was a multiple of 1 inch. Equally important, the wakes remaining at the inlet to the test cascade would be greatly reduced as a result of closer spacing.

Figure A.1 shows the details of the inlet guide vane unit, while Fig. A.2 shows the assembly in relation to the bellmouth contraction and the side walls. Figure A.3 shows the mechanism to adjust the inlet guide vanes. Figure A.4 shows a view of the IGV assembly from the north side. A view of the Cascade Wind Tunnel partially assembled (north side wall off) is shown in Fig. A.5.

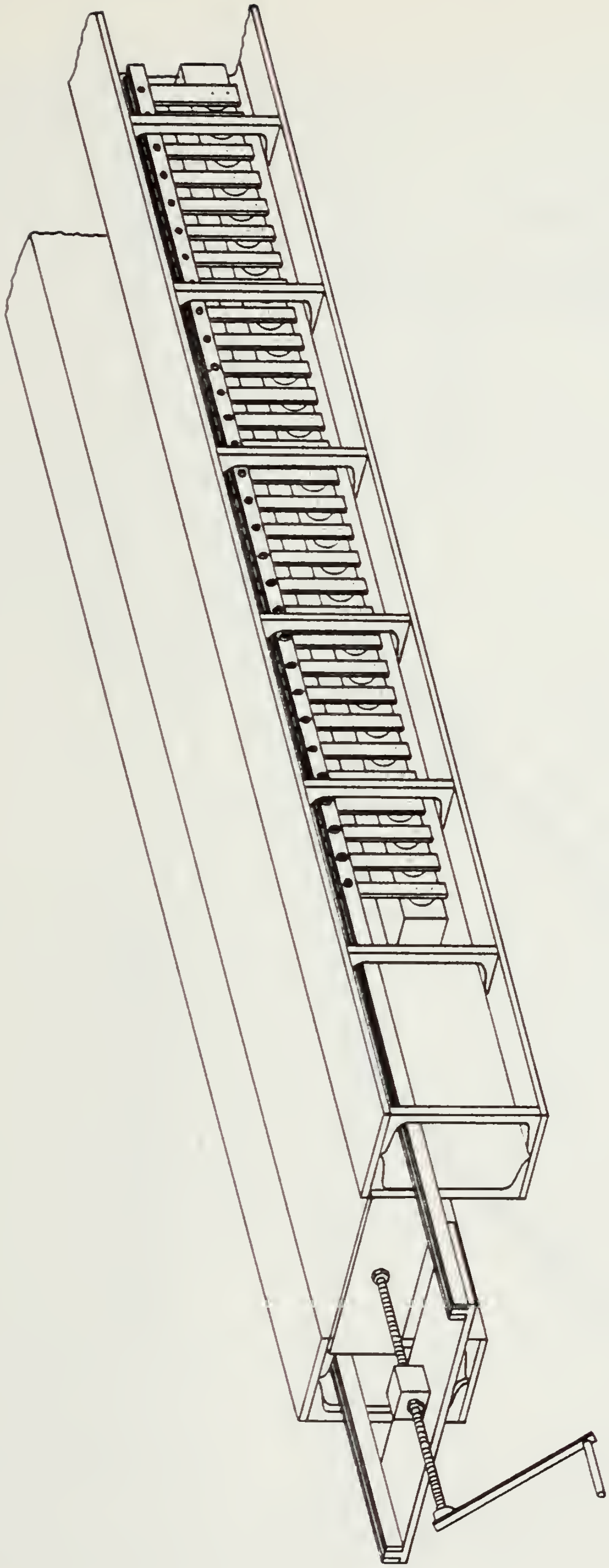


Fig. A.1. Inlet Guide Vane Assembly

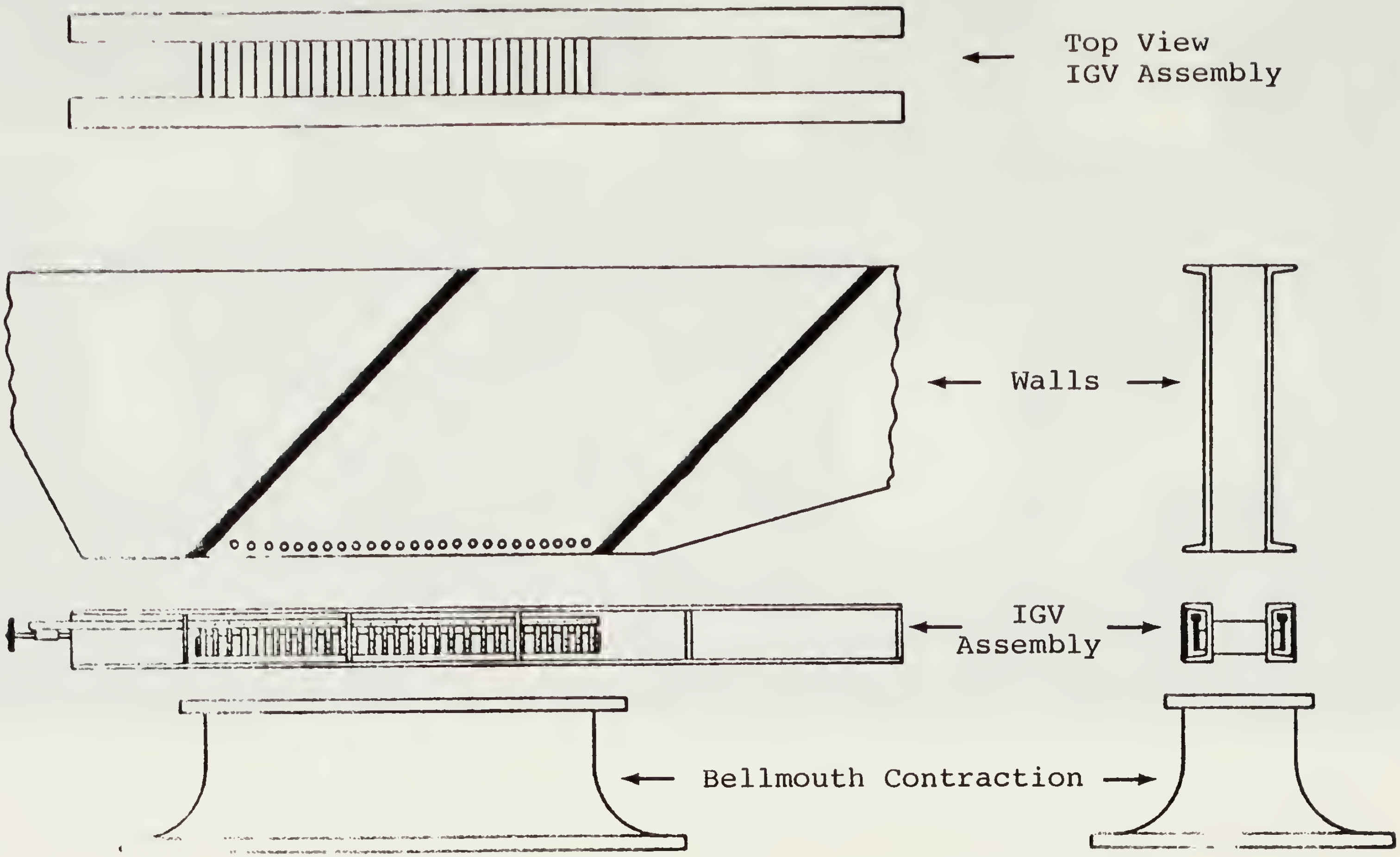


Fig. A.2. Cascade Wind Tunnel Sub-Assemblies

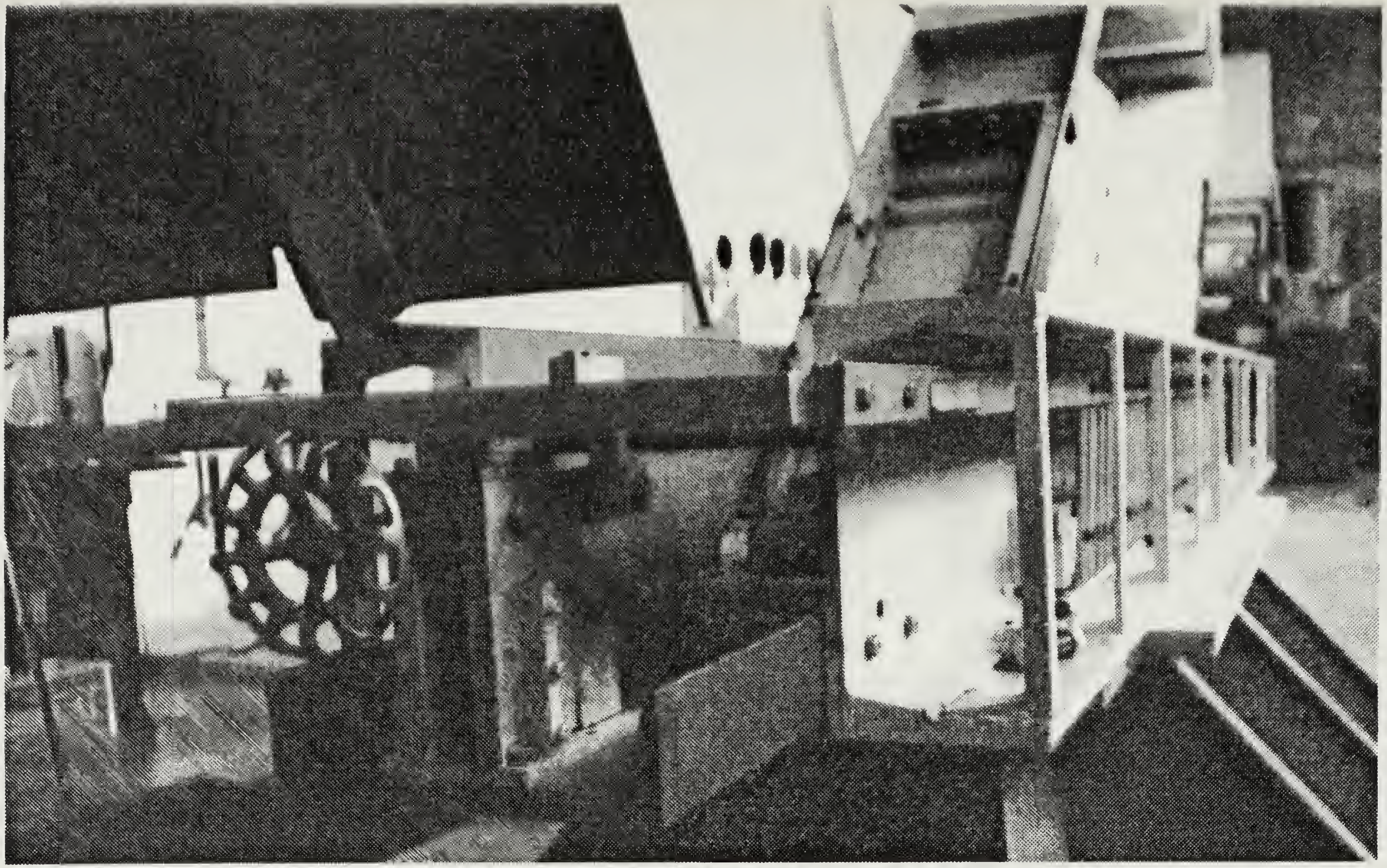


Fig. A.3. View of the IGV Adjustment Mechanism

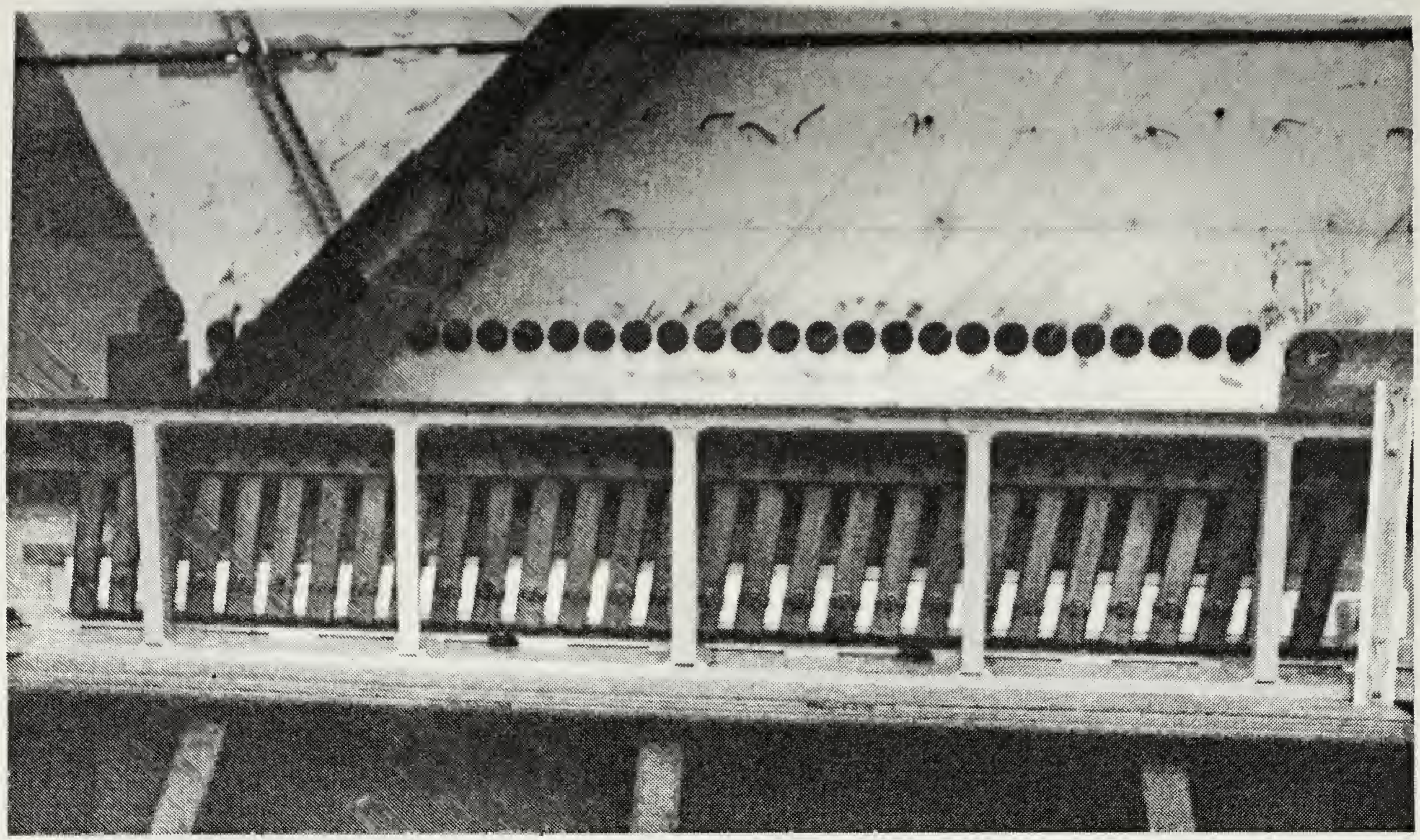


Fig. A.4. Side View of the IGV Assembly

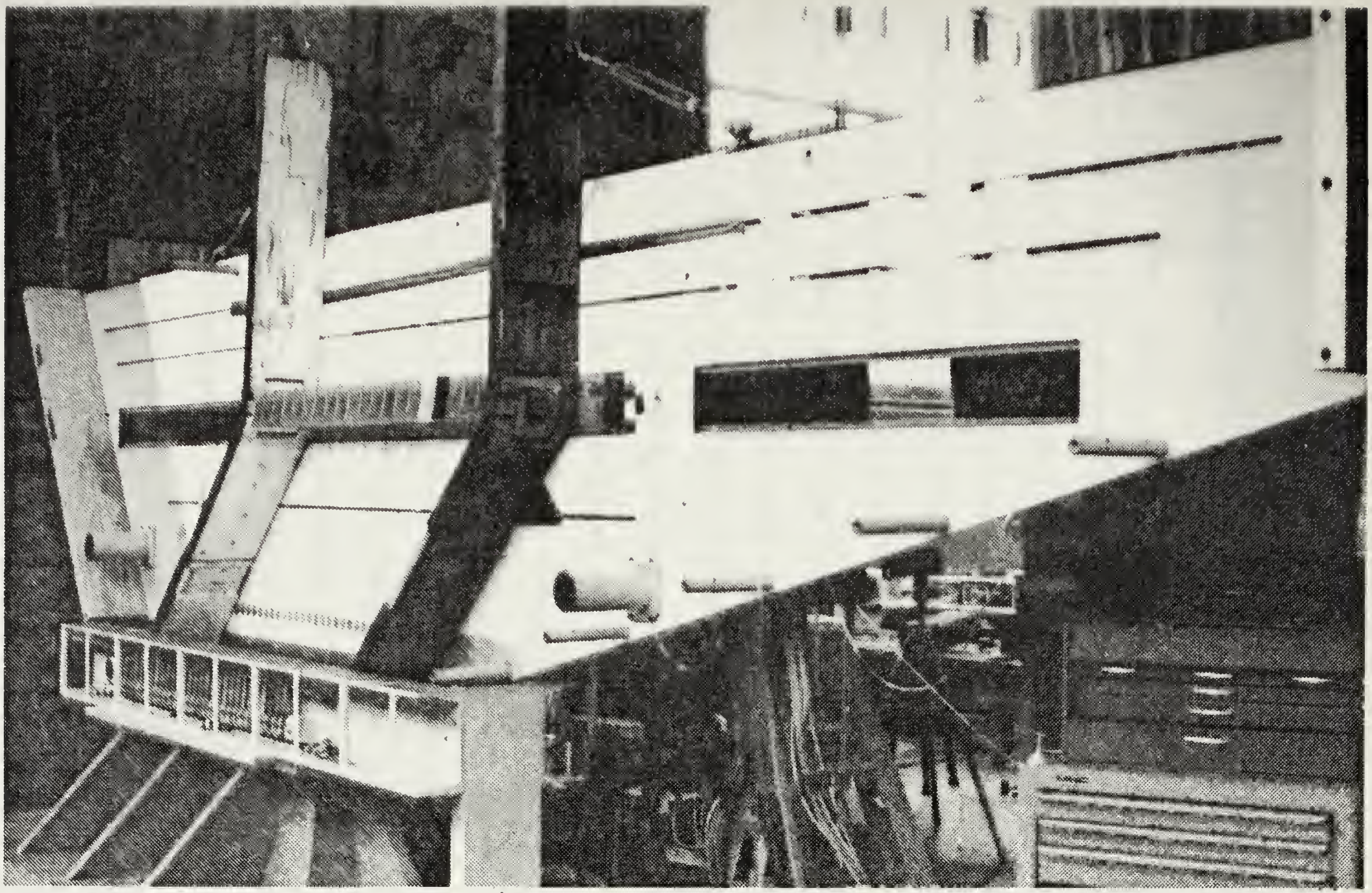


Fig. A.5. View of the Subsonic Cascade Wind Tunnel (North Wall Removed)

APPENDIX B

SELECTION AND INSTALLATION OF SCREEN MATERIAL

Pankhurst and Holder [Ref. 17] show that the turbulence of an airstream can be increased by placing a coarse mesh across the flow upstream of the test section. One of the most effective methods which is used for the reduction of turbulence and non-uniformities also consists of placing a mesh screen across the tunnel. Screens used for this purpose are of a finer mesh and are placed at a greater distance from the test section, and normally in the low-speed region upstream of the contraction in a conventional subsonic wind tunnel. By using such a screen the large scale eddies are removed at the expense of the introduction of a greater number of smaller eddies which decay rapidly.

McEligot [Ref. 16] investigated the possibilities of reducing non-uniformities in the test section of the subsonic cascade wind tunnel. His investigation and recommendations were completed while the inlet guide vanes were still at 2 inch spacings. McEligot concluded that some modification was necessary to achieve one percent uniformity for the mean velocity at the test cascade inlet plane and suggested several options. One of the options suggested was placing the turning vanes (inlet guide vanes) at a closer pitch. As explained in Appendix A, the pitch of the inlet

guide vanes was reduced from 2 inches to 1 inch. This new inlet guide vane arrangement did result in a one percent uniformity for the mean velocity at the test cascade inlet plane.

The other approach suggested was the use of wire gauze screens. McEligot showed that the velocity distribution appeared to be largely dependent on a pressure drop coefficient K, defined by the equation

$$K = \frac{p_1 - p_2}{\frac{1}{2} \rho V^2}$$

where p_1 and p_2 are the pressures upstream and downstream of the screen respectively. This pressure drop coefficient depends mainly on the blockage coefficient β defined by the equation

$$\beta = (1 - d/\ell)^2$$

where d is the diameter of wire used in the screen and ℓ is the distance between the wires. This blockage coefficient is commonly referred to as "percent open area" in catalogues of industrial wire cloth and woven wire screens.

For the velocities and flow angles used in the cascade wind tunnel, McEligot recommended using a wire gauze screen with a resistance coefficient, K, of 2.2 and a blockage coefficient, β, of 0.47. However, since the new inlet guide vane arrangement resulted in a one percent uniformity for

the mean velocity and the pressure drop across a screen with a blockage coefficient of 0.47 was expected to be higher than could be tolerated for the desired test conditions, screens with a slightly higher blockage coefficient (higher percent of open area) were selected to be tested.

The screens tested were of the following configurations:

MESH	WIRE DIAMETER (inches)	BLOCKAGE COEFFICIENT
4	.0410	.6989
5	.0410	.6320
16	.0105	.6922

Until the effectiveness of wire gauze screen in reducing non-uniformities in this facility was proven, a temporary installation of the screen material was considered adequate for testing purposes. The test screen was installed in the cascade wind tunnel by placing it between the inlet guide vane assembly and the north and south end walls. This arrangement placed the screen 7.25 inches downstream of the inlet guide vanes and 19.3 inches upstream of the lower test plane. Figure B.1 shows the installation of the wire gauze screen.

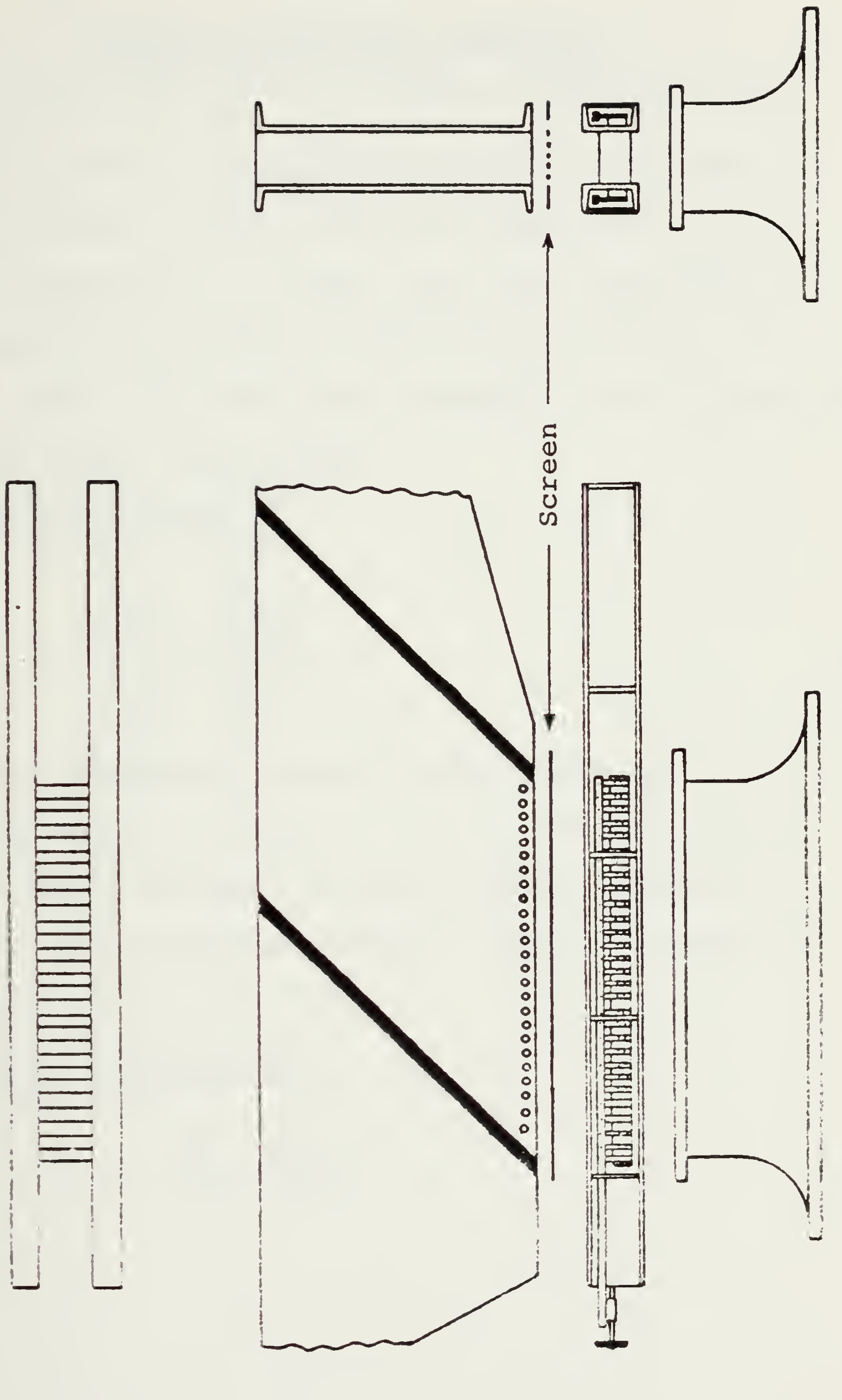


Fig. B.1. Screen Installation

APPENDIX C

CASCADE PERFORMANCE PARAMETERS

(by F. S. Cina; reproduced with minor changes from Ref. 7)

The performance of a cascade is specified in terms of the deviation angle (δ) and the loss coefficient ($\bar{\omega}$) for given inlet conditions. In Ref. 1 the loss coefficient is shown to correlate in terms of the Diffusion Factor (D). In the present work, the performance parameters were calculated using the following expressions:

1. Loss Coefficient ($\bar{\omega}$)

$$\bar{\omega} = \frac{\bar{C}_{p_{t_1}} - \bar{C}_{p_{t_2}}}{\bar{C}_{p_{t_1}} - \bar{C}_{p_1}} \tag{1}$$

where the mass averaged pressure coefficients in Eq. (1) are defined in Appendix C of Ref. 7. It is shown in Appendix C of Ref. 7 that the effect of time dependent supply conditions are removed and the effect of AVDR is included in the use of Eq. (1).

2. Diffusion Factor (D)

$$D = 1 - \frac{W_2}{W_1} + \frac{\Delta W_u}{2\sigma W_1} \tag{2}$$

3. Pressure Rise

$$C_{p_{static}} = \frac{\bar{P}_2 - \bar{P}_1}{\bar{Q}_1} \tag{3}$$

4. Blade Surface Pressure Coefficients

$$C_{p1} = \frac{P_s - \bar{P}_1}{\bar{Q}_1} \tag{4}$$

$$C_{p2} = \frac{P_s - \bar{P}_2}{\bar{Q}_2} \tag{5}$$

5. Dimensionless Velocity

$$X = \frac{V}{V_t} = \frac{V}{\sqrt{2C_pT_t}}$$

where V is the local velocity, $V_t = \sqrt{2C_pT_t}$ is the "limiting" velocity and T_t is the stagnation temperature.

APPENDIX D

INSTRUCTIONS FOR PREPARING INPUT AND OPERATING QSONIC USING A RECTILINEAR CASCADE CONFIGURATION

D.1 BACKGROUND INFORMATION

QSONIC has the capability to calculate an axial, mixed or radial flow field and the test cascade can be rotating or stationary. The geometry of the streamsurface can be a 2D planar cascade or axisymmetric with varying channel thickness and radial position. The capabilities of QSONIC, beyond those of previous cascade analysis methods (such as described in Ref. 8) include the ability to calculate through weak shocks with a peak relative Mach number less than 1.4, and completely around both leading and trailing edge regions of a blade profile. The blade shapes in the leading and trailing edge regions are not restricted to circular arcs. Detailed instructions for preparing input for a configuration other than an axial flow, stationary and rectilinear cascade may be found in Ref. 9. What follows are instructions for preparing the input applicable to the Rectilinear Cascade facility and running QSONIC on the Naval Postgraduate School's computer and associated operating system. It is assumed that the reader has a working knowledge of the NPS computer operating system and is familiar with Refs. 13 and 14.

QSONIC operates in two parts. The first part generates a body (blade) centered mesh (geometry generation). The second part actually solves for the flow conditions at points in the mesh (flow solution). The data necessary to generate a mesh consists of a two-dimensional description of the blade shape. This is in the form of pairs of (X,Y) points on the surface, together with parameters that describe the cascade layout, such as chord and stagger angle. Additionally, parameters describing the density of mesh lines complete the input for the geometry generation.

For flow field calculations, the upstream flow conditions, convergence criteria and a schedule of meshes to be used should be input. If quasi-three dimensional effects are to be considered, a data file containing a description of the streamchannel's radial thickness and position as a function of distance along the stream surface is needed. For the case described herein, this was input by assuming a linear reduction in streamchannel thickness using a factor of 1/AVDR. This gave excellent results. (The output of another NASA code, Meridl [Ref. 15], can be used to input data to QSONIC for compressor flow field calculations. This program has recently become operational on the NPS computer.)

The output of QSONIC consists of listings which contain an echo print of the input data, generated mesh coordinates on the blade surface, progress reports on the flow convergence and a list of the final velocities, pressures

and densities on the blade surface for each grid that was included in the schedule of solution meshes.

D.2 INPUT DESCRIPTION

The input for QSONIC falls into the following categories:

- Logical and case control parameters (NAMELIST PARAMS)
- Bulk data input:
  - For geometry generation runs (NAMELIST INSTUFF)
  - For flow solution runs:
    - Mesh point storage files
    - Streamchannel data file (for quasi-3D)

The following is a description of the logical and case control parameters for the Rectilinear Cascade. Except for TITLE, the format for all these variables is in namelist form. The namelist is PARAMS. This information is taken from Ref. 9 and adapted to the Cascade Wind Tunnel. Namelist variables can be entered in any order. If a default value is listed, it is not necessary to enter that particular variable. If the default value is listed as none, then a value for that parameter must be input.

The following parameters apply to both the mesh generation and the flow solution runs, but the values need not be the same.

Variable Name	Type	Default Value	Description
TITLE	Alphameric	None	This is a one-line name for the case being run. TITLE must appear on the first line of the data file that will be referred to as NAMELIST DATA.
NOFLOW	Logical	False	NOFLOW = .TRUE. if a run is to stop after generating a mesh, such as the mesh generation run. NOFLOW = .FALSE. for the flow solution run.
MS	Integer	None	MS is an array (max. dimension 10) of values (max. value = 25) for the number of grid lines in the mesh that will enclose the blade. 25 is a satisfactory number for blades of solidity near unity. As solidity increases the maximum value in MS should decrease.
NOZES	Integer	None	NOZES is an array (max. dimension 10) of values (max. value = 49) for the number of grid lines in the mesh radiating from the blade on one surface. If a value of NOZES is greater than zero, a mesh with that many lines will be developed and stored in the file MESHGEN DATA. If the value is negative, QSONIC assumes that this MESH already exists in the file MESHGEN DATA and will be read in. For Geometry Generation runs NOZES > 0 and for flow solution runs NOZES < 0. For electrostatic analog grid generator, NOZES must be odd.

BETA1	Real	None	BETA1 is the flow angle at the upstream boundary, in degrees. BETA1 is measured from the aerodynamic chordline to the direction of flow; clockwise is negative. This can be obtained from the output of the cascade tunnel data reduction program 'CX4431'. It is listed as "inlet air angle." Because of a difference in definition, it is necessary to use the usual inlet air angle minus the stagger angle for BETA1. Example: The output of CX4431 lists an inlet air angle of 42.429°. The cascade is configured with a stagger angle of 14.27°. $\begin{array}{r} 42.429^\circ \\ -\ 14.27 \\ \hline 28.16 \end{array} = \text{BETA1}$
BETA2	Real	None	BETA2 is the flow angle at the downstream boundary in degrees. It is measured from the aerodynamic chordline to direction of flow. Clockwise is negative. This can be obtained from the output of the cascade tunnel data reduction program 'CX4431'. It is listed as outlet air angle. Because of a difference in definition, it is necessary to use the outlet air angle minus the stagger angle for BETA2.
GAMMA	Real	1.4	This is the ratio of specific heats. For the Subsonic Cascade Wind Tunnel the default value works well.
TOLS	Real	None	This is an array of dimension 10 of tolerances corresponding to MS and NOZES. Each grid solution will proceed until its TOLS value is satisfied.

MESH1	Integer	1	This is an index in the arrays MS and NOZES of the first mesh to be generated and/or used for the flow solution. For geometry generation runs, MESH1 selects one of the grids to be stored, provided NOZES(MESH1) > 0.
MESHN	Integer	None	This is an index in the arrays MS and NOZES of last grid to be calculated for geometry generation runs or used for the flow solution. For geometry generation runs, MESHN = MESH1. Subsequent flow solution runs then solve the case for all grids listed in MS and NOZES between index MESH1 and MESHN. For flow solution MESH1 normally points to the coarsest mesh. To insure equal spacing of grid lines over the entire mesh, $\frac{\text{NOZES(I)} - 1}{\text{K(I} - \text{MESH1)}} = \text{Integer},$ where MESH1 $\leq$ I $\leq$ MESHN and K = 2, 3, 4, . . . (K = 2 if grid lines are doubled between successive grids).
LAMDA0	Real	None	Stagger angle of the blade row in degrees measured from the throughflow direction to the blade chord line. (Clockwise is negative.)
CHORD	Real	None	True chord of the blade, in the same units as the blade coordinates.
S	Real	None	Blade spacing in the same units as the blade coordinates.

The following parameters are required only for the geometry generation run. QSONIC gives the user a choice of two grid (mesh) generators. The Electrostatic Analog grid generator is applicable to any blade shape and any value of stagger or turning. The interpolation scheme grid generator works for most blades except those with sharp leading edges where the edge radius is less than .5% of chord. The interpolation scheme allows the user to concentrate grid lines in areas of high interest around the blade. With the Electrostatic Analog grid generator no concentration of grid lines is available. For the cascade configuration used in this study, the interpolation scheme provided gross errors in the flow solutions, so the Electrostatic Analog grid generator was used with good results.

Name	Type	Default	Description
NED	Integer	None	Total number of body definition coordinates that are input. These are the X,Y points that describe the profile of the blade, with the first point repeated as the last point.
KN	Integer	None	KN is used to indicate which grid generator is to be used. KN = 0 will call the electrostatic analog grid generator. For interpolation scheme, KN = number of body points on upper surface from the minimum to maximum X points, inclusive.

NED and KN are required for either grid generator. If the electrostatic analog grid generator is used, no other

parameters are used. If this grid generator is used the value from NOZES that is used must be odd.

The following parameters are used only if the Interpolation Scheme is used to generate the mesh.

Name	Type	Default	Description
RLE	Real	None	RLE is the leading edge radius of the blade, with units the same as the coordinates defining the blade profile.
RTE	Real	None	RTE is the trailing edge radius of blade.
THETL	Real	0	THETL is the camber angle of the leading edge in degrees. It is measured from the aerodynamic chord to the line tangent to the mean camber line at the leading edge; clockwise is positive.
THETT	Real	0	THETT is the camber angle at the trailing edge in degrees. It is measured from the chord line to the mean camber line at the trailing edge. Clockwise is positive.
CAMPER	Integer	6	For blades whose chordline lies outside the blade profile, such as the DCA blading discussed in this report, extra grid lines surrounding the blade are needed to interpolate the blade position. The truncated value of MS( )/CAMPER is added to MS( ). The maximum allowed value of MS( ) + MS( )/CAMPER is 30 grid lines. These are the grid lines that enclose the blade profile.
STABAC	Real	0.999	STABAC is used only for test cases where no blade shape is to be input. Default value is usually adequate.

CHOP	Real	0.99	If leading edge or trailing edge radius is less than 2% of chord consult Ref. 9 for clarification. Normally, $0.9 < CHOP < 1.0$.
SMOOTH	Logical	False	For automatic addition of more blade definition points in the region of the leading and trailing edges set SMOOTH = .TRUE. This should be done for all blades except cusps and wedges.
LEONLY	Logical	False	LEONLY = .TRUE. for smoothing about the leading edge only; this is used if the trailing edge is a cusp or a wedge. SMOOTH must also be .TRUE.
SLP1 SLP2 SLP3 SLP4	Real Real Real Real	1 2 1 1	These parameters control the concentration of grid lines, if desired. The default values worked well for the DCA blades reported herein. For controlling the amount and location of the concentration consult Ref. 9.

The following logical and case control parameters are required only for flow solution runs.

Name	Type	Default	Description
MINF	Real	None	This is the Mach number at the upstream boundary. This can be determined from the nondimensional velocity X output from the cascade tunnel data reduction program 'Redd 5' and the relationship, $\frac{\gamma - 1}{2} M^2 = \frac{X^2}{1 - X^2}$ which yields $M = \left\{ \frac{X^2}{1 - X^2} \cdot \frac{2}{\gamma - 1} \right\}^{1/2}$

TOLS(I) is the tolerance for MS(I) and NOZES(I). There are three forms of input permitted.

A) $-1.0 < \text{TOLS(I)} < 0.0$: Calculations of the flow solution will proceed until the relative circulation error

$$\left| \frac{C^N_{CALC} - C_{EXACT}}{C_{EXACT}} \right| < |\text{TOLS(I)}|$$

TOLS values between -10^{-3} and -10^{-6} are typical values for grids. This method of input is appropriate only for lifting (non-symmetric blades) cases.

B) $0.0 < \text{TOLS(I)} < 1.0$: Calculations of the flow solution will proceed until the average relative change in potential is less than the absolute value of TOLS(I).

$$\left(\frac{\delta\phi}{\phi}\right)_{AVE} < |\text{TOLS(I)}|$$

Typical values should be between 10^{-3} and 10^{-5}.

C) $1.0 < \text{TOLS(I)}$: Calculations proceed until the number of iterations equals TOLS(I).

Regardless of TOLS input, the solution for each grid will stop after 300 iterations if the TOLS criteria has not yet been made. All three forms were used for the cascade configuration reported herein with no discernible differences in results.

OVEREL	Real	1.5	The default values of these parameters are adequate for flow conditions in the subsonic cascade wind tunnel.
UNDERL	Real	1.0	
SUPREL	Real	1.0	
NOWREL	Integer	20	
NOTYET	Integer	2	
TEGARD	Real	2.0	
DAMP	Real	1.0	
CII	Real	0.2	
IT	Integer	10	Number of iterations between intermediate printouts of residuals and Mach number. The information controlled by this parameter is of limited value in comparing with measured data, so a value greater than 10 reduces the amount of computer printout. For the study reported herein 40 was used.
ALLOUT	Logical	.FALSE.	To list the flow quantities at all grid points in the last mesh set ALLOUT = .TRUE.. Unless a very coarse grid is used, the output resulting from ALLOUT = .TRUE. would be extremely voluminous and of limited value. Until the cascade is configured so it is possible to take data from between the blades, ALLOUT should be .FALSE..
QUASI3	Logical	.FALSE.	QUASI3 = .TRUE. to activate streamchannel thickness and/or radius variations. The cascade wind tunnel has no radius variations, but to simulate 3-D effects the streamchannel thickness is reduced at the exit boundary by a factor of 1/AVDR. This data is placed in a file used by QSONIC if a quasi 3-D solution is desired.
NSTRM	Integer	1	This is the position of desired streamsurface data on the streamchannel file used if QUASI3 = .TRUE.. Currently the default value of 1 identifies the proper streamsurface data

			in the streamchannel file. If the output from the NASA code 'Meridl' is used for the streamchannel data, then by using different values of NSTRM, different streamsurface data may be used.
RINF	Real	1.0	This is the spanwise radius at the upstream boundary divided by aerodynamic chord. Radius effects are activated if RINF $\neq$ 1.0. The current version of QSONIC allows the following cases.

	QUASI	RINF	Results
1)	.FALSE.	1.0	Planar 2D flow
2)	.TRUE.	$\neq$ 1.0	Thickness on file; radius on file.
3)	.TRUE.	1.0	Thickness on file; constant radius.

Only 1) and 3) apply to the cascade wind tunnel.

WAKE	Real	0.0	These parameters apply only if the test cascade is rotating and/or the downstream Mach is near 1.0.
MINF2	Real	10.0	
OMEGA	Real	0.0	
VAXIAL	Real	999.0	
FLOCO	Real	999.0	

At this point all of the logical and case control parameters necessary to use QSONIC for the flow conditions possible in the subsonic cascade wind tunnel have been discussed. The following is a description of the Bulk Data input for the geometry generation run and the flow solution run.

The format for all variables in the bulk data for mesh generation (geometry) is namelist form. The namelist is INSTUFF.

Name	Type	Default	Description
H2	Complex	None	This is a table of points defining the blade profile. The real part = X, and imaginary part = Y coordinate. The table begins at the point of maximum X value at the trailing edge and proceeds clockwise back around to the first point, which is repeated. The blade must be at the stagger angle and the origin at the point of minimum X. For Electrostatic Analog grids, the stagger angle must be positive (leading edge low, trailing edge high). The maximum number of points in H2 is 99 for the interpolation scheme or 63 for the Electrostatic Analog.
BUG2	Logical	.FALSE.	BUG2 = .TRUE. for a more detailed output of geometry generation. This will include the X,Y coordinates that define the mesh as well as second derivatives at grid points on the body. Except for trouble shooting this data is of limited value at the present time since there is no graphic output.

The bulk data for flow solutions consists of a mesh file and the streamchannel data file if quasi-3D effects are to be calculated. The mesh file is created by QSONIC during the mesh (grid) generation run. No further inputs are required from the user for the mesh file.

The streamchannel data file must contain a table of streamtube thicknesses, radial positions and corresponding X values along the streamsurface.

Name	Type	Default	Description
CHO	Real	None	CHO is the aerodynamic chord multiplied by the cosine of LAMDA0. (LAMDA0 ≡ stagger angle)
NRSP	Integer	None	NRSP is the total number of data points in each of the tables of thickness, radial position, and X location. If NRSP is 2, a linear distribution is obtained between the endpoints given. NRSP = 2 was used for the study reported herein with good results.
RM	Real	None	Array of corresponding X locations for thickness and radius data values. X = 0 represents the leading edge of blade, with the blade at stagger angle. The units can be any consistent length scale common to CHO, RM, RMSP and BESP. Inches were used in this study.
RMSP	Real	None	Spanwise radial positions of streamsurface at the X locations given in RM. RMSP was not used in the current study.
BESP	Real	None	Array of streamtube thickness values at the X locations specified in RM. For the study reported herein, at X = 0 a streamtube thickness of 1.0 was arbitrarily selected. The streamtube contraction through the test section was similated by reducing the thickness at X = 0, by a factor of 1/AVDR at the trailing edge. Duval [Ref. 3] explains AVDR.

D.3 PREPARING INPUT FILES

QSONIC was originally configured to use several input/output devices while reading data and generating output. The input/output devices are listed below as used by QSONIC.

I/O Unit	Usage
2	File containing streamchannel data. This is used only if QUASI = .TRUE..
5	Standard card input; NAMELISTS PARAMS, INSTUF.
6	Standard printed output.
13	For mesh generation runs, coordinates of all mesh points are written here. For flow solutions, X, Y, velocities, pressures and MACH are recorded for graphic display. The program currently has no graphic output capability. No user action is necessary to create this file.
18	Used as temporary storage. No output is stored here. No user action is necessary in conjunction with this file.
23	Previously developed mesh coordinates are read in from this file during the flow solution. After a mesh generation run, the user must create this file and put in it the data from I/O unit 13, so that during the flow solution QSONIC can read in the mesh points.

QSONIC is presently configured to operate with the CMS system of the IBM 370 computer. This system provides a high degree of flexibility in parameter selection. With this system, all the input/output units previously mentioned are on the disk space assigned to the Turbopropulsion Laboratory (TPL). Access to QSONIC and the TPL disk space can be obtained through the Director of TPL.

The first step in using QSONIC is the creation of the data file necessary for the mesh generation run. This is done using the standard procedures of the XEDIT function of the CMS operating system. Reference 14 has specific instructions for creating new files. The filename and filetype for the data used in this study was NAMELIST GEOMD. Once the data file is opened, the necessary data is input beginning at column 2 of the virtual card. Since the variables are in namelist form, they can be input in any order.

Table D.1 is an example of the data file necessary for the mesh generation run. The TITLE must appear on the first line (FORMAT = 20A4). After the TITLE, the logical and case control parameters are input after the namelist &PARAMS. When all the case control parameters required are input the PARAMS namelist is closed with &END. On the next line of the data file the bulk data for the mesh generation run is input in namelist form, with the namelist &INSTUF. The H1 = 100*(0.0,0.0) that appears after &INSTUF on Table D.1 was used on earlier versions of QSONIC, but is not used in the present version. It should, however, appear in the data file before the H2 variables (X,Y coordinates defining the blade profile).

At this point, some discussion of the coordinates defining the blade profile is warranted. Table D.2 is a listing of the X and Y coordinates of the DCA blading used in this study. Figure D.1 is a plot of these coordinates.

Recall that the coordinates defining the blade profile for QSONIC must be for the blade at the stagger angle and minimum X at the origin. The coordinates of Table D.2 were translated and rotated using a coordinate transformation routine for the HP-67 programmable calculator. These new coordinates appear in the namelist INSTUFF on Table D.1. Figure D.2 is a plot of the translated and rotated coordinates. It is highly recommended that such a plot be made for any new blade profiles, to ensure that the original coordinates are translated and rotated properly.

The second step in using QSONIC is the creation of the data files necessary for the flow solution run. The file used for the flow solution in this report is on the TPL disk space with a filename/filetype of NAMELIST FLOWD. The simplest way to open this data file is to use the XEDIT function, as discussed in Ref. 14, to start a new file. Then input the same data as is in the data file for the mesh generation run using the XEDIT subcommand GET (filename) (filetype). The appropriate changes and additions can then be made to this file. Table D.3 is an example of the data file just discussed.

Two more data files are required for the flow solution. The data for one of these is created by the mesh generation run. The other file contains the streamchannel thickness data for implementing quasi-3D effects.

After the mesh generation run, a file with the filename/filetype MESHGEN DATA will appear on the disk. Create a new file with the filename/filetype MESHIN DATA. This is most easily done by issuing the command 'XEDIT MESHIN DATA'; then use 'GET MESHGEN DATA'. This file contains the previously developed mesh coordinates.

The streamchannel data file should have the filename/filetype of DATA5D DATA. The format for the data file is shown below.

Virtual Card	Column No.	Variable Name
1	BLANK	
2	BLANK	
3	21-30	CHO
4	BLANK	
5	36-40	NRSP
6	BLANK	
7	BLANK	
8		
9		
10		
11		
12 ↓ As needed	1-80 (8F10.5)	RM
↓ As needed	1-80 (8F10.5)	RMSP (not used in this study)
	1-80 (8F10.5)	BESP

Table D.4 is an example of the data file used in the present study. Since NRSP = 2 was used for this study a

linear distribution is assumed for the streamtube thickness values and only 2 values of RM and BESP are required; therefore, only 1 virtual card was required for each array.

D.4 PROGRAM OUTPUT

The output generated by QSONIC for the geometry generation run includes a printed listing (I/O unit 6) and a mesh point file (I/O unit 13). The printed listing under the CMS system I/O unit 6 is normally the computer terminal unless the command 'FILEDEF 06 PRINTER' has been invoked. It is unusual for the program to run properly the first time, so initially it is helpful to have the printed listing appear at the terminal. Once the program is running properly the output should be sent to the line printer.

The flow solution run output consists of a printed listing (I/O unit 6) and a plot data save file (I/O unit 13). Once the flow solution is running properly the printed listing should be sent to the line printer.

Table D.5 is an example of the output generated by the geometry generation run. Figure D.3 is a plot of the grid output points on the blade surface, horizontal chord, produced by the mesh generation run. Figure D.4 is a plot of the grid output points with the blade at the stagger angle. Table D.6 is an example of the output generated by the flow solution.

A detailed explanation of the printed output for the program QSONIC may be found in Ref. 9.

D.5 RUNNING THE PROGRAM

The files on the TPL disk space that apply to QSONIC are listed below:

QSONIC EXEC	A1
QSONIC FORTRAN	A1
QSONIC TEXT	A1
NAMELIST GEOM	A1
NAMELIST FLOW	A1
NAMELIST GEOMD	A1
NAMELIST FLOWD	A1
DATA5 DATA	A1
DATA5D DATA	A1

QSONIC EXEC sets the input/output devices required to read and store data. QSONIC FORTRAN is the source program. To document the changes to QSONIC necessary to use the code with the IBM 370 operating system and serve as a reference for future users, a program listing is included at the end of this appendix. QSONIC TEXT is the computer executable code created when QSONIC FORTRAN is compiled. NAMELIST GEOM and NAMELIST FLOW are the data files for the geometry generation and flow generation respectively for the example in Ref. 9. DATA5 DATA is the streamchannel data required for the quasi-3D solution for the example in Ref. 9.

NAMELIST GEOMD is the data file for the geometry generation for the DCA blading used in the study reported herein. NAMELIST FLOWD is the file for the flow solution for the cascade configuration used in this study.

QSONIC expects the input data to be in a file on the TPL disk space named NAMELIST DATA. Since the first time QSONIC is run is to develop the body centered mesh, the file NAMELIST GEOMD must be renamed NAMELIST DATA, using procedures specified in Ref. 13. Because QSONIC requires large amounts of virtual memory, extra storage must be defined for the code to operate. This is accomplished by issuing the command 'DEFINE STORAGE 1504K'.

With the data file renamed and more storage defined, type 'QSONIC' to load the program. The output will appear on the terminal screen unless FILEDEF Ø6 PRINTER was invoked prior to loading the program.

After the mesh generation is complete, rename NAMELIST DATA to NAMELIST GEOMD and change NAMELIST FLOWD to NAMELIST DATA. Create a data file with the filename/filetype MESHIN DATA. The elements of this file are the same as the elements in the file MESHGEN DATA that was created by the mesh generation run. The necessary input/output files are now configured for a flow solution run. Issue the command 'QSONIC' to begin execution.

If the program output appears at the terminal it is possible to have some I/O error messages appear with the

output. This is because the write statements in QSONIC are formatted for the 132 character long line of the printer. These errors do not affect the validity of the program output.

The explanation for any error or condition message generated by QSONIC can be found in Ref. 9.

D.6 QSONIC UPDATE

Recently an improved version of QSONIC was reported by NASA Lewis Research Center [Ref. 13]. The new version requires less virtual memory and executes approximately 30% faster than the version presently in use at NPS. Also, the output appears in a different format than is described in this appendix. Reference 18 describes the most recent version of QSONIC in detail.

TABLE D.1. INPUT DATA FOR MESH GENERATION RUN OF QSONIC

```
      NASA DCA BLADES, GEOMETRY GEN  42.4,5.3
&PARAMS NOFLOW=.TRUE.,RESTAR=.FALSE.,REMESH=4,
MS=3,5,10,15,NOZES=9,13,25,49,MESH1=4,MESHN=4,LAMDA0=14.27,
CHORD=5.01,S=3.0,NED=51,KN=0,RLE=0.44,RTE=0.44,
THETL=-45.72,THETT=45.72,CAMPER=5,STABAC=0.999,CHOP=0.99,
SMOOTH=.TRUE.,LEONLY=.FALSE.
&END
&INSTUF
H1=100*(0.0,0.0)
H2= (0.48554E+01, 0.12616E+01),(0.48095E+01, 0.12066E+01)
(0.47426E+01, 0.12102E+01),(0.45112E+01, 0.12153E+01)
(0.42827E+01, 0.12170E+01),(0.40545E+01, 0.12096E+01)
(0.38285E+01, 0.11975E+01),(0.36030E+01, 0.11793E+01)
(0.33812E+01, 0.11549E+01),(0.31591E+01, 0.11232E+01)
(0.29391E+01, 0.10879E+01),(0.27205E+01, 0.10467E+01)
(0.25038E+01, 0.9978),(0.22877E+01, 0.9428),(0.20745E+01, 0.8845)
(0.18621E+01, 0.8191),(0.16499E+01, 0.7486),(0.14402E+01, 0.6726)
(0.12322E+01, 0.5898),(0.10257E+01, 0.5011),(0.8201, 0.4045)
(0.6158, 0.3071),(0.4137, 0.2010),(0.2134, 0.882E-01)
(0.656E-01, 0.0),(0.0, 0.267E-01),(0.126E-01, 0.701E-01)
(0.1801, 0.2190),(0.3701, 0.3726),(0.5633, 0.5135),(0.7588, 0.6458)
(0.9584, 0.7657),(0.11592E+01, 0.8766),(0.13630E+01, 0.9759)
(0.15693E+01, 0.10655E+01),(0.17783E+01, 0.11486E+01)
(0.19897E+01, 0.12179E+01),(0.22017E+01, 0.12811E+01)
(0.24183E+01, 0.13341E+01),(0.26362E+01, 0.13782E+01)
(0.28562E+01, 0.14135E+01),(0.30795E+01, 0.14362E+01)
(0.33055E+01, 0.14524E+01),(0.35325E+01, 0.14565E+01)
(0.37639E+01, 0.14514E+01),(0.39971E+01, 0.14354E+01)
(0.42334E+01, 0.14109E+01),(0.44717E+01, 0.13704E+01)
(0.47147E+01, 0.13197E+01),(0.48232E+01, 0.12947E+01)
(0.48554E+01, 0.12616E+01),48*(0.0, 0.0)
BUG2= F
&END
```

TABLE D.2. TEST BLADE COORDINATES

X-COORD.	Y-PRESS.	Y-SUCT.
-0.044	0.000	0.000
-0.021	-----	0.039
0.013	-0.042	-----
0.178	0.007	0.142
0.400	0.067	0.244
0.622	0.120	0.333
0.844	0.164	0.413
1.067	0.207	0.480
1.289	0.242	0.538
1.511	0.271	0.584
1.733	0.293	0.620
1.956	0.309	0.649
2.178	0.320	0.664
2.399	0.324	0.673
2.622	0.324	0.671
2.844	0.318	0.660
3.066	0.304	0.640
3.288	0.284	0.607
3.511	0.260	0.567
3.732	0.229	0.515
3.955	0.191	0.453
4.177	0.147	0.380
4.400	0.098	0.298
4.621	0.040	0.200
4.844	-0.022	0.091
4.908	-0.042	-----
4.943	-----	0.040
4.966	0.000	0.000

TABLE D.3. INPUT DATA FOR FLOW SOLUTION RUN OF QSONIC

```
        NASA DCA BLADES, FLOW SOLUTION   42.4,5.3
&PARAMS NOFLOW=.FALSE.,RESTAR=.FALSE.,REMESH=4,
MS=3,5,10,15,NOZES=-9,-13,-25,-49,KN=0,NED=51,
MESH1=1,MESHN=4,LAMDA0=14.27,CHORD=5.01,
S=3.0,MINF=0.3127,BETA1=28.16,BETA2=-12.42,
GAMMA=1.4,TOLS=1.E+04,-2.E-05,7.E-05,6.E-05,-.000001,2*0.,
OVEREL=1.5,UNDERL=1.,SUPREL=1.0,NOWREL=20,NOTYET=10,
CII=0.40,IT=40,ALLOUT=.FALSE.,QUASI3=.TRUE.,NSTRM=1,
RINF=1.,WAKE=0.,MINF2=10.0,OMEGA=0.
&END
&INSTUF
H1=100*(0.0,0.0)
H2= (0.48554E+01, 0.12616E+01),(0.48095E+01, 0.12066E+01)
(0.47426E+01, 0.12102E+01),(0.45112E+01, 0.12153E+01)
(0.42827E+01, 0.12170E+01),(0.40545E+01, 0.12096E+01)
(0.38285E+01, 0.11975E+01),(0.36030E+01, 0.11793E+01)
(0.33812E+01, 0.11549E+01),(0.31591E+01, 0.11232E+01)
(0.29391E+01, 0.10879E+01),(0.27205E+01, 0.10467E+01)
(0.25038E+01, 0.9978),(0.22877E+01, 0.9428),(0.20745E+01, 0.8845)
(0.18621E+01, 0.8191),(0.16499E+01, 0.7486),(0.14402E+01, 0.6726)
(0.12322E+01, 0.5898),(0.10257E+01, 0.5011),(0.8201, 0.4045)
(0.6158, 0.3071),(0.4137, 0.2010),(0.2134, 0.882E-01)
(0.656E-01, 0.0),(0.0, 0.267E-01),(0.126E-01, 0.701E-01)
(0.1801, 0.2190),(0.3701, 0.3726),(0.5633, 0.5135),(0.7588, 0.6458)
(0.9584, 0.7657),(0.11592E+01, 0.8766),(0.13630E+01, 0.9759)
(0.15693E+01, 0.10655E+01),(0.17783E+01, 0.11486E+01)
(0.19897E+01, 0.12179E+01),(0.22017E+01, 0.12811E+01)
(0.24183E+01, 0.13341E+01),(0.26362E+01, 0.13782E+01)
(0.28562E+01, 0.14135E+01),(0.30795E+01, 0.14362E+01)
(0.33055E+01, 0.14524E+01),(0.35325E+01, 0.14565E+01)
(0.37639E+01, 0.14514E+01),(0.39971E+01, 0.14354E+01)
(0.42334E+01, 0.14109E+01),(0.44717E+01, 0.13704E+01)
(0.47147E+01, 0.13197E+01),(0.48232E+01, 0.12947E+01)
(0.48554E+01, 0.12616E+01),48*(0.0, 0.0)
BUG2= F
&END
```

TABLE D.4. DATA FILE FOR QUASI-3D SOLUTION

```
STREAMLINE DATA FOR DCA1
            4.8554
                              2


    0.0   4.85500
1.00000   0.98476
```

TABLE D.5. SAMPLE OUTPUT FROM MESH GENERATION RUN

```
1 QSONIC VERSION 1.4.9.1                NASA DCA BLADES, GEOMETRY GEN  42.4,5.3
0     CASE CONTROL INPUT ECHO

 &PARAMS
 NOFLOW=T,RESTAR=F,REMESH=             4,MS=          3,          5,          10,
           0,          0,              0,NOZES=          9,          13,          25,
           0,          0,              0,MESH1=              4,MESHN=             4,LAMDA0=
   3.00000000     ,NED=           51,KN=          0,RLE=  .439999998     ,RTE=  .439
   45.7200012     ,CAMPER=              5,STABAC=  .999000013     ,CHOP=  .990000010
   2.00000000     ,SLP3=  1.00000000     ,SLP4=  1.00000000     ,MINF=  .0
 GAMMA=  1.39999962     ,TOLS=  .0               ,  .0              ,  .0              ,
   .0            ,  .0              ,  .0              ,  .0              ,OVEREL=  1.
   1.00000000     ,NOWREL=              0,NOTYET=              2,TEGARD=  2.00000000     ,
          10,ALLOUT=F,QUASI3=F,NSTRM=              1,RINF=  1.00000000     ,WAKE=  .0
   .0            ,FLOCO=  999.000000     ,MINF2=  10.0000000
 &END
1                                          ELECTROSTATIC ANALOG GRID GENERATED
     NEGRID=  15 NZGRID,ODD=  49 IMAXY=  20
           SURFACE COORDINATES
           0.0130938    0.0
           0.0          0.0053293
           0.0025150    0.0139920
           0.0359481    0.0437126
           0.0738722    0.0743712
           0.1124351    0.1024950
           0.1514571    0.1289021
           0.1912974    0.1528343
           0.2313771    0.1749700
           0.2720558    0.1947904
           0.3132334    0.2126747
           0.3549501    0.2292613
           0.3971457    0.2430938
           0.4394611    0.2557086
           0.4826945    0.2662873
           0.5261875    0.2750897
           0.5700998    0.2821357
           0.6146706    0.2866666
           0.6597804    0.2899002
           0.7050898    0.2907186
           0.7512773    0.2897005
           0.7978243    0.2865070
           0.8449900    0.2816167
           0.8925548    0.2735330
           0.9410577    0.2634132
           0.9627146    0.2584230
           0.9691417    0.2518162
           0.9599799    0.2408383
           0.9466268    0.2415569
```

TABLE D.5 (Continued)

0.9004390	0.2425748
0.8548302	0.2429141
0.8092813	0.2414372
0.7641715	0.2390220
0.7191616	0.2353892
0.6748901	0.2305188
0.6305587	0.2241917
0.5866467	0.2171457
0.5430139	0.2089220
0.4997605	0.1991616
0.4566267	0.1881836
0.4140718	0.1765469
0.3716765	0.1634930
0.3293214	0.1494211
0.2874650	0.1342515
0.2459480	0.1177245
0.2047305	0.1000199
0.1636926	0.0807385
0.1229141	0.0612974
0.0825748	0.0401198
0.0425948	0.0176048
0.0130938	0.0

NUMBER OF BODY POINTS 51 PITCH 0.5988023 CHO 0.969
ITER COUNT FOR INTERNAL GRID POINTS= 72 ERR= 0.93749E-05
1 GRID OUTPUT POINTS ON BLADE SURFACE, CHORD AT ST

I	X	Y
0	0.46779E+00	0.13229E+00
1	0.46963E+00	0.12825E+00
2	0.46774E+00	0.12400E+00
3	0.46393E+00	0.12059E+00
4	0.45698E+00	0.11813E+00
5	0.44414E+00	0.11793E+00
6	0.42698E+00	0.11879E+00
7	0.40705E+00	0.11922E+00
8	0.38426E+00	0.11950E+00
9	0.35902E+00	0.11939E+00
10	0.33189E+00	0.11886E+00
11	0.30367E+00	0.11774E+00
12	0.27457E+00	0.11613E+00
13	0.24473E+00	0.11402E+00
14	0.21441E+00	0.11129E+00
15	0.18384E+00	0.10789E+00
16	0.15318E+00	0.10385E+00
17	0.12266E+00	0.99302E-01
18	0.92137E-01	0.94288E-01
19	0.61648E-01	0.88725E-01

TABLE D.5 (Cont'd)

20	0.31281E-01	0.82462E-01
21	0.13252E-02	0.75573E-01
22	-0.28214E-01	0.68206E-01
23	-0.57339E-01	0.60491E-01
24	-0.86180E-01	0.52330E-01
25	-0.11461E+00	0.43743E-01
26	-0.14254E+00	0.34746E-01
27	-0.17005E+00	0.25421E-01
28	-0.19707E+00	0.15731E-01
29	-0.22356E+00	0.56539E-02
30	-0.24939E+00	-0.47077E-02
31	-0.27451E+00	-0.15315E-01
32	-0.29883E+00	-0.26158E-01
33	-0.32227E+00	-0.36951E-01
34	-0.34480E+00	-0.47608E-01
35	-0.36650E+00	-0.58174E-01
36	-0.38734E+00	-0.68631E-01
37	-0.40685E+00	-0.78844E-01
38	-0.42504E+00	-0.88796E-01
39	-0.44122E+00	-0.97884E-01
40	-0.45542E+00	-0.10637E+00
41	-0.46752E+00	-0.11329E+00
42	-0.47730E+00	-0.11777E+00
43	-0.48484E+00	-0.12019E+00
44	-0.49043E+00	-0.12067E+00
45	-0.49468E+00	-0.11925E+00
46	-0.49685E+00	-0.11593E+00
47	-0.49483E+00	-0.11077E+00
48	-0.48883E+00	-0.10379E+00
49	-0.47905E+00	-0.94958E-01
50	-0.46696E+00	-0.84229E-01
51	-0.45218E+00	-0.71829E-01
52	-0.43554E+00	-0.58480E-01
53	-0.41686E+00	-0.44022E-01
54	-0.39721E+00	-0.29501E-01
55	-0.37669E+00	-0.15007E-01
56	-0.35583E+00	-0.10023E-02
57	-0.33468E+00	0.12473E-01
58	-0.31339E+00	0.25319E-01
59	-0.29199E+00	0.37531E-01
60	-0.27072E+00	0.49044E-01
61	-0.24951E+00	0.59877E-01
62	-0.22830E+00	0.70028E-01
63	-0.20712E+00	0.79567E-01
64	-0.18598E+00	0.88653E-01
65	-0.16492E+00	0.97197E-01
66	-0.14400E+00	0.10509E+00
67	-0.12308E+00	0.11244E+00
68	-0.10198E+00	0.11932E+00
69	-0.80804E-01	0.12573E+00
70	-0.59691E-01	0.13173E+00
71	-0.38546E-01	0.13727E+00
72	-0.17271E-01	0.14231E+00
73	0.40976E-02	0.14690E+00
74	0.25543E-01	0.15109E+00
75	0.47074E-01	0.15483E+00
76	0.68671E-01	0.15801E+00
77	0.90393E-01	0.16068E+00
78	0.11239E+00	0.16291E+00
79	0.13459E+00	0.16470E+00
80	0.15682E+00	0.16605E+00
81	0.17914E+00	0.16693E+00
82	0.20164E+00	0.16727E+00
83	0.22428E+00	0.16709E+00
84	0.24699E+00	0.16644E+00
85	0.26976E+00	0.16530E+00
86	0.29250E+00	0.16374E+00
87	0.31517E+00	0.16172E+00
88	0.33742E+00	0.15919E+00
89	0.35926E+00	0.15617E+00
90	0.38027E+00	0.15278E+00
91	0.40063E+00	0.14895E+00
92	0.41936E+00	0.14518E+00
93	0.43656E+00	0.14176E+00
94	0.45123E+00	0.13848E+00
95	0.46149E+00	0.13541E+00
96	0.46779E+00	0.13229E+00
97	0.46963E+00	0.12825E+00
98	0.46774E+00	0.12400E+00

TABLE D.6. SAMPLE OUTPUT FROM FLOW SOLUTION RUN

```
CSCNIC VERSION 1.4.5.1            NASA DCA BLADES, FLOW SOLUTION   42.4.5.3
    CASE CONTROL INPUT ECHO
&PARAMS                               4,MS=         3,         5,        10,        15,        0,        0,        0,
NCFLOW=F,RESTAR=F,REMESH=             0,ICZES=        -9,       -13,       -25,       -49,        0,        0,        0,
        0,           0,               0,MESH1=         1,MESHN=             4,LAMDA0=  14.2700005  ,CHCRD=  5.01000023  ,S=
        0,           0,          51,KA=           0,RLE=    .0          ,RTE=    .1          ,THETI=   .0          ,THETT=
  3.00000000    ,NED=               6,STABAC=  .99000013   ,CHOP=  .95000001   ,SMOOTH=F,LECNLY=F,SLP1=  1.00000000   ,SLP2=
   .0           ,CAMFER=                 ,SLP4=  1.00000000   ,MINF=  .31269974   ,BETA1=   28.1600037   ,BETA2= -12.4200001   ,
  2.00000000    ,SLP3=  1.00000000  ,TOLS=  10000.0000    , -.20000001068E-04,  .69999999946E-04,  .60000000058E-04, -.10000000034E-15,  .0
CAPMA=  1.39999962  ,  .0           ,  .0           ,  .0           ,OVERFL=  1.50000000   ,UNDERL=  1.00000000   ,SUPREL=
   .0           ,NCHREL=            20,NOTYET=           10,TEGARD=  2.00000000   ,DAMP=  1.00000000   ,CII=  .35999576   ,IT=
  1.00000000        40,ALLOUT=F,QUASI3=T,ASTRM=      1,RINF=  1.00000000   ,WAKE=  .0        ,OMEGA=  .0        ,VAXIAL=
                   ,FLCCC=  959.000000    ,MINF2=  10.0000000
   .0
&END


CALCULATED FLOW PARAMETERS
&CONST
CIRCLN=  .369831126    ,MINF2=  .228250086    ,B2081=  .984759986    ,R2CR1=  1.00000000    ,RINF=  1.00000000    ,RATLE=
  1.00000000
&END
```

TABLE D.6 (Continued)

RELAXATION BEGINS ON GRID OF 3 SURFACE CONTOURS INTERSECTED BY 17 RADIATING LINES

SUPERSONIC RELAXATION PARAMETER, SUPREL= 0.10000E+01

ITERATION COUNT	AVERAGE PHI CORRECTN	RESIDUAL AT T. C.	MAX MACH ON BLADE	CALCULATED CIRCULATION	RELATIVE CIRC ERROR	SUBSONIC RELAX. FAC.	SUPERSONIC RELAX. FAC.
40	0.131169E-01	0.889250E-02	0.313030E+00	-0.203196E-01	-0.105212E+01	0.150000E+01	0.100000E+01
80	0.115749E-01	0.889165E-02	0.313030E+00	-0.651576E-01	-0.116714E+01	0.150000E+01	0.100000E+01
120	0.747400E-02	0.889185E-02	0.313030E+00	-0.109995E+00	-0.128216E+01	0.150000E+01	0.100000E+01
160	0.577930E-02	0.889184E-02	0.313030E+00	-0.154808E+00	-0.139711E+01	0.150000E+01	0.100000E+01
200	0.471108E-02	0.889184E-02	0.313030E+00	-0.199630E+00	-0.151229E+01	0.150000E+01	0.100000E+01
240	0.397760E-02	0.889172E-02	0.313030E+00	-0.244452E+00	-0.162707E+01	0.150000E+01	0.100000E+01
280	0.344233E-02	0.889150E-02	0.313030E+00	-0.289275E+00	-0.174205E+01	0.150000E+01	0.100000E+01
300	0.322454E-02	0.889149E-02	0.313030E+00	-0.311687E+00	-0.179954E+01	0.150000E+01	0.100000E+01

FINAL FLOW CALCULATION ON BLADE SURFACE FOR THE 3 BY 17 MESH

RADIATING LINE NO.	X/CX	Y/CX	X	Y	MACH	STATIC PRES COEF	PHI	XVEL	YVEL	DENSITY
1	1.00000	0.26029	0.46563	0.12825	0.22825	-0.25555	1.79549	0.71344	-0.05291	1.02289
2	0.93444	0.25043	0.40705	0.11922	0.22825	0.37082	1.63616	0.72002	0.07404	1.02285
3	0.76437	0.24538	0.24473	0.11402	0.22825	0.41461	-0.67092	0.72530	0.06198	1.02278
4	0.57256	0.21888	0.06165	0.08573	0.22753	0.46929	-0.80653	0.71730	0.14047	1.02284
5	0.38799	0.17175	-0.11461	0.04374	0.23588	0.42828	-0.93923	0.72277	0.22641	1.02085
6	0.22037	0.10587	-0.27459	-0.01531	0.27133	0.23670	-1.07328	0.79929	0.34281	1.01155
7	0.08171	0.04331	-0.40685	-0.07884	0.30578	0.04462	-1.21174	0.87197	0.44070	1.00218
8	0.0	0.0	-0.48404	-0.12019	0.31270	-2.51582	-0.65550	0.55387	0.72185	0.95595
9	0.00607	0.02643	-0.47905	-0.09496	0.31270	-1.62470	-2.69583	0.50606	0.79545	0.95596
10	0.11336	0.11020	-0.37669	-0.01591	0.31270	-0.06332	3.97190	0.82486	0.56148	1.00010
11	0.24655	0.18855	-0.24952	0.05587	0.28420	0.16083	-0.77707	0.81172	0.41201	1.00785
12	0.37901	0.24372	-0.12308	0.11244	0.27598	0.21751	-0.65663	0.83539	0.28154	1.01061
13	0.51226	0.27583	0.00410	0.14690	0.29268	0.11854	-0.53463	0.91835	0.18635	1.00579
14	0.64698	0.29847	0.13459	0.16470	0.28158	0.18256	-0.41129	0.89571	0.06523	1.00891
15	0.79060	0.29911	0.26976	0.16530	0.22825	5636.39062	-0.29356	20.03418	-2.44723	0.50591
16	0.92771	0.28198	0.40063	0.14895	0.22825	5614.02344	4.32653	20.07785	-2.59297	0.45596
17	1.00000	0.26029	0.46563	0.12825	0.22825	11.55704	1.48380	0.97500	-0.07226	0.95988

END OF CALCULATION ON GRID 1 OF 4

TABLE D.6 (Continued)

RELAXATION BEGINS ON GRID OF 5 SURFACE CONTOURS INTERSECTED BY 25 RADIATING LINES

SUPERSONIC RELAXATION PARAMETER, SUPREL= 0.600000E+00

ITERATION COUNT	AVERAGE PHI CORRECTN	RESIDUAL AT T. E.	MAX MACH ON BLADE	CALCULATED CIRCULATION	RELATIVE CIRC ERROR	SUBSONIC RELAX. FAC.	SUPERSONIC RELAX. FAC.
40	0.216941E-02	-0.180530E-02	0.419742E+00	0.390200E+00	0.947207E-03	0.150000E+01	0.600000E+00
55	0.113744E-02	0.195710E-03	0.410352E+00	0.389837E+00	0.139138E-04	0.150000E+01	0.600000E+00

FINAL FLOW CALCULATION ON BLADE SURFACE FOR THE 5 BY 25 MESH

RADIATING LINE NO.	X/CX	Y/CX	X	Y	MACH	STATIC PRES COEF	PHI	XVEL	YVEL	DENSITY
1	1.00000	0.25667	0.46563	0.12825	0.20406	0.49614	-0.08157	0.65456	0.03833	1.02414
2	0.97356	0.26596	0.44413	0.11793	0.24991	0.33317	-0.10249	0.78854	0.14505	1.01673
3	0.88530	0.24747	0.35502	0.11539	0.24523	0.38189	-0.17239	0.78715	0.01052	1.01860
4	0.76677	0.24191	0.24473	0.11402	0.22662	0.47420	-0.25808	0.72556	0.05994	1.02318
5	0.64029	0.22664	0.12267	0.09937	0.22358	0.48081	-0.34508	0.70553	0.11241	1.02379
6	0.51436	0.20214	0.00132	0.07557	0.22341	0.48956	-0.43535	0.69695	0.16360	1.02392
7	0.39414	0.16903	-0.11461	0.04374	0.22944	0.46035	-0.52030	0.70229	0.22038	1.02241
8	0.28115	0.12553	-0.22356	0.01565	0.22870	0.46369	-0.60856	0.68485	0.26586	1.02257
9	0.17981	0.06535	-0.32227	-0.03695	0.24044	0.40285	-0.68443	0.65969	0.32604	1.01962
10	0.09118	0.04190	-0.40685	-0.07884	0.21171	0.52105	-0.76353	0.66031	0.31347	1.02535
11	0.02816	0.01218	-0.46752	-0.11329	0.21547	0.48223	-0.79844	0.65583	0.22161	1.02347
12	0.0	0.0	-0.49469	-0.11925	0.38120	-0.81702	-0.81540	0.85487	0.81308	0.95573
13	0.01621	0.02519	-0.47505	-0.09496	0.48645	-1.38177	-0.77773	1.00261	1.16082	0.93149
14	0.08170	0.07801	-0.41686	-0.04402	0.41463	-0.72818	-0.65978	1.05044	0.79328	0.96414
15	0.16592	0.13660	-0.33468	0.01247	0.37555	-0.43017	-0.53546	1.01533	0.63184	0.97988
16	0.25424	0.18576	-0.24552	0.05987	0.35730	-0.24872	-0.42277	1.01963	0.50815	0.98535
17	0.34197	0.22446	-0.16492	0.09720	0.34776	-0.22238	-0.31880	1.03375	0.40310	0.98661
18	0.43519	0.25405	-0.08081	0.12573	0.33987	-0.17856	-0.22133	1.04087	0.30625	0.99125
19	0.51724	0.27651	0.00419	0.14693	0.33186	-0.12541	-0.12733	1.03644	0.21254	0.99386
20	0.60673	0.29029	0.09039	0.16008	0.32225	-0.06250	-0.03578	1.02309	0.11819	0.99692
21	0.69876	0.29677	0.17514	0.16693	0.30965	0.01670	0.05444	0.99013	0.02654	1.00082
22	0.79273	0.29509	0.26576	0.16530	0.29366	0.11413	0.14219	0.93854	-0.05506	1.00557
23	0.88555	0.28561	0.35526	0.15617	0.27294	0.23328	0.22434	0.86612	-0.12315	1.01138
24	0.96571	0.27067	0.43656	0.14176	0.22317	0.47305	0.24009	0.69089	-0.19073	1.02302
25	1.00000	0.25667	0.46563	0.12825	0.20423	0.49529	0.30926	0.65511	0.03827	1.02410

END OF CALCULATION ON GRID 2 OF 4

TABLE D.6 (Continued)

RELAXATION BEGINS ON GRID OF 15 SURFACE CONTOURS INTERSECTED BY 49 RADIATING LINES

SUPERSONIC RELAXATION PARAMETER, SUPREL= 0.50000E+00

ITERATION COUNT	AVERAGE PHI CORRECTN	RESIDUAL AT T. E.	MAX MACH ON BLADE	CALCULATED CIRCULATION	RELATIVE CIRC ERROR	SUBSONIC RELAX. FAC.	SUPERSONIC RELAX. FAC.
40	0.715658E-03	-0.160764E-03	0.382182E+00	0.389971E+00	0.358700E-03	0.150000E+01	0.500000E+00
80	0.176843E-03	-0.338110E-04	0.385213E+00	0.309848E+00	0.443496E-04	0.150000E+01	0.500000E+00
120	0.697097E-04	-0.136988E-04	0.384399E+00	0.285838E+00	0.177362E-04	0.150000E+01	0.500000E+00

FINAL FLOW CALCULATION ON BLADE SURFACE FOR THE 15 BY 49 MESH

RADIATING LINE NO.	X/CX	Y/CX	X	Y	MACH	STATIC PRES COEF	PHI	XVEL	YVEL	DENSITY
1	1.00000	0.25760	0.46963	0.12825	0.13741	0.58914	-0.04226	0.40573	0.17519	1.02864
2	0.99415	0.24965	0.46393	0.12059	0.25638	0.19990	-0.04935	0.72465	0.38651	1.00575
3	0.97357	0.24685	0.44413	0.11753	0.28225	0.17222	-0.06591	0.80245	0.05963	1.00841
4	0.93512	0.24623	0.40705	0.11922	0.24776	0.36733	-0.09584	0.79499	-0.01584	1.01755
5	0.88532	0.24640	0.35902	0.11539	0.23182	0.45495	-0.13613	0.74132	0.00953	1.02215
6	0.82793	0.24670	0.30368	0.11774	0.22423	0.48043	-0.17641	0.71966	0.03331	1.02367
7	0.76681	0.24704	0.24473	0.11492	0.22194	0.51179	-0.21055	0.70769	0.05785	1.02441
8	0.70265	0.23648	0.18385	0.10789	0.21975	0.50707	-0.26179	0.70126	0.08149	1.02467
9	0.64025	0.22758	0.12267	0.09930	0.21987	0.50679	-0.30542	0.69802	0.10948	1.02466
10	0.57579	0.21661	0.06165	0.08873	0.22139	0.50425	-0.34521	0.69515	0.13597	1.02453
11	0.51444	0.20297	0.00132	0.07557	0.22195	0.49706	-0.39303	0.69384	0.16485	1.02419
12	0.45761	0.18734	-0.05734	0.06049	0.22405	0.48739	-0.43645	0.69414	0.19073	1.02371
13	0.39423	0.16997	-0.11461	0.04374	0.22573	0.47941	-0.47959	0.69243	0.21562	1.02333
14	0.33674	0.15097	-0.17005	0.02542	0.22707	0.47305	-0.52208	0.68854	0.24091	1.02352
15	0.28126	0.13048	-0.22356	0.00565	0.22832	0.46703	-0.56381	0.68322	0.26675	1.02273
16	0.22844	0.10874	-0.27450	-0.01531	0.22584	0.45962	-0.60433	0.67768	0.29291	1.02238
17	0.17892	0.08630	-0.32227	-0.03695	0.23184	0.45512	-0.64320	0.67199	0.31337	1.02215
18	0.13316	0.06430	-0.36651	-0.05817	0.22967	0.46166	-0.67959	0.66037	0.32744	1.02247
19	0.09122	0.04287	-0.40685	-0.07884	0.22572	0.47942	-0.71280	0.64001	0.34098	1.02333
20	0.05555	0.02312	-0.44122	-0.09708	0.22115	0.50086	-0.74101	0.61751	0.35168	1.02437
21	0.02631	0.00715	-0.46752	-0.11329	0.23281	0.57781	-0.76245	0.58437	0.28961	1.02809
22	0.01036	0.0	-0.48484	-0.12019	0.12594	0.80755	-0.77368	0.39303	0.15126	1.03518
23	0.00015	0.00047	-0.49468	-0.11725	0.46514	-2.65762	-0.77397	0.13725	-1.43851	0.86640
24	0.0	0.00976	-0.49483	-0.11177	0.34735	-3.54031	-0.75000	0.51966	-0.03267	0.81972
25	0.01636	0.02016	-0.47905	-0.09496	0.42428	-0.60151	-0.71873	0.98465	0.91771	0.96055
26	0.04422	0.05014	-0.45218	-0.07183	0.39787	-0.59262	-0.67287	0.97617	0.80446	0.97086
27	0.08034	0.07697	-0.41686	-0.04402	0.38930	-0.49052	-0.61727	0.97622	0.73668	0.97590
28	0.12245	0.10505	-0.37669	-0.01591	0.37726	-0.43392	-0.55733	0.98564	0.68081	0.97845
29	0.16605	0.13755	-0.33468	0.01247	0.37195	-0.46053	-0.49742	1.00678	0.62453	0.98034
30	0.21031	0.16353	-0.29199	0.03753	0.36673	-0.36310	-0.43516	1.02119	0.56811	0.98218
31	0.25435	0.18670	-0.24952	0.05987	0.36108	-0.32318	-0.38345	1.03156	0.51064	0.98415
32	0.29932	0.20711	-0.20711	0.07956	0.35539	-0.28306	-0.33006	1.03696	0.45741	0.98612
33	0.34207	0.22540	-0.16492	0.09729	0.35165	-0.25142	-0.27660	1.04177	0.40738	0.98773
34	0.38545	0.24120	-0.12303	0.11244	0.34583	-0.21742	-0.22907	1.04515	0.35466	0.98935
35	0.42928	0.25498	-0.08081	0.12573	0.34075	-0.18287	-0.18053	1.04368	0.30649	0.99104
36	0.47310	0.26694	-0.03854	0.13726	0.33630	-0.15327	-0.13319	1.04193	0.25994	0.99250
37	0.51731	0.27693	0.00417	0.14659	0.33216	-0.12565	-0.08652	1.03524	0.21345	0.99385
38	0.56184	0.28515	0.04709	0.15403	0.32765	-0.09658	-0.04342	1.03384	0.16573	0.99527
39	0.60675	0.29122	0.09039	0.16068	0.32200	-0.05963	0.00502	1.02262	0.11567	0.99708
40	0.65261	0.29538	0.13459	0.16470	0.31548	-0.01804	0.05024	1.00620	0.07110	0.99912
41	0.69881	0.29765	0.17914	0.16693	0.30955	0.02521	0.09480	0.98662	0.02631	1.00123
42	0.74560	0.29787	0.22427	0.16710	0.30017	0.07666	0.13983	0.96049	-0.01630	1.00375
43	0.79276	0.29601	0.26976	0.16530	0.29045	0.13460	0.18190	0.92859	-0.05463	1.00657
44	0.83985	0.29225	0.31517	0.16172	0.27958	0.19768	0.22357	0.89119	-0.09032	1.00965
45	0.88557	0.28654	0.35926	0.15617	0.26543	0.27539	0.26256	0.84177	-0.12573	1.01348
46	0.92846	0.27905	0.40063	0.14895	0.24805	0.36369	0.29720	0.78254	-0.14620	1.01796
47	0.96571	0.27160	0.43656	0.14176	0.22901	0.46266	0.32531	0.71753	-0.16223	1.02252
48	0.99157	0.26501	0.46149	0.13541	0.17384	0.66371	0.34344	0.50833	-0.23369	1.03224
49	1.00000	0.25760	0.46963	0.12825	0.13755	0.58829	0.34758	0.40616	0.17527	1.02860

END OF CALCULATION ON GRID 3 OF 4

TABLE D.6 (Continued)

RELAXATION BEGINS ON GRID OF 15 SURFACE CONTOURS INTERSECTED BY 97 RADIATING LINES

SUPERSONIC RELAXATION PARAMETER, SUPREL= 0.50000E+00

ITERATION COUNT	AVERAGE PHI CORRECTN	RESIDUAL AT T. E.	MAX MACH ON BLADE	CALCULATED CIRCULATION	RELATIVE CIRC ERROR	SUBSONIC RELAX. FAC.	SUPERSONIC RELAX. FAC.
40	0.842054E-04	-0.341284E-04	0.381786E+00	0.389843E+00	0.314971E-04	0.150000E+01	0.500000E+00
54	0.586785E-04	-0.273761E-04	0.382888E+00	0.389340E+00	0.229348E-04	0.150000E+01	0.500000E+00

FINAL FLOW CALCULATION ON BLADE SURFACE FOR THE 15 BY 97 MESH

RADIATING LINE NO.	X/CX	Y/CX	X	Y	MACH	STATIC PRES COEF	PHI	XVEL	YVEL	DENSITY
1	1.00000	0.25756	0.46563	0.12825	0.04384	0.82554	-0.03818	0.17131	0.11397	1.04004
2	0.99474	0.25315	0.46774	0.12400	0.23020	0.39126	-0.04046	0.46586	0.57035	1.01506
3	0.99411	0.24563	0.46293	0.12059	0.31951	-0.06778	-0.04535	0.88529	0.50842	0.99571
4	0.98692	0.24708	0.45693	0.11813	0.32722	-0.12617	-0.05356	1.02703	0.19377	0.99392
5	0.97762	0.24688	0.44413	0.11793	0.29199	0.12106	-0.06641	0.93477	-0.01409	1.00591
6	0.95588	0.24777	0.42698	0.11879	0.25982	0.30647	-0.08129	0.83281	-0.03039	1.01494
7	0.93525	0.24821	0.40705	0.11922	0.24444	0.38775	-0.09722	0.78452	-0.01326	1.01889
8	0.91167	0.24856	0.38426	0.11959	0.23665	0.42657	-0.11477	0.76002	-0.00302	1.02077
9	0.88556	0.24838	0.35902	0.11939	0.23133	0.45275	-0.13370	0.74296	0.00883	1.02204
10	0.85745	0.24783	0.33189	0.11886	0.22770	0.47011	-0.15367	0.73117	0.02158	1.02288
11	0.82629	0.24608	0.30268	0.11774	0.22540	0.48106	-0.17420	0.72345	0.03424	1.02341
12	0.79317	0.24512	0.27457	0.11613	0.22367	0.48920	-0.19523	0.71723	0.04519	1.02380
13	0.76730	0.24283	0.24473	0.11402	0.22209	0.49656	-0.21665	0.71134	0.05717	1.02416
14	0.72593	0.24011	0.21441	0.11129	0.22103	0.50151	-0.23830	0.70668	0.07196	1.02440
15	0.70431	0.23649	0.18385	0.10789	0.22077	0.50269	-0.26011	0.70425	0.08561	1.02446
16	0.67258	0.23230	0.15218	0.10385	0.22117	0.50134	-0.28207	0.70347	0.09979	1.02439
17	0.64191	0.22760	0.12267	0.09931	0.22125	0.50049	-0.30400	0.70241	0.10997	1.02435
18	0.60542	0.22241	0.09214	0.09429	0.22096	0.50183	-0.32599	0.69561	0.12125	1.02442
19	0.57787	0.21666	0.06165	0.08873	0.22165	0.50321	-0.34757	0.69493	0.13525	1.02448
20	0.54645	0.21018	0.03128	0.08246	0.22107	0.50125	-0.36956	0.69409	0.15138	1.02439
21	0.51545	0.20305	0.00132	0.07557	0.22224	0.49586	-0.39184	0.69444	0.16646	1.02413
22	0.48485	0.19543	-0.02821	0.06821	0.22340	0.49145	-0.41365	0.69520	0.17877	1.02396
23	0.45475	0.18744	-0.05734	0.06049	0.22408	0.48730	-0.43532	0.69438	0.19020	1.02371
24	0.42472	0.17910	-0.08618	0.05233	0.22450	0.48531	-0.45652	0.69230	0.20250	1.02362
25	0.39550	0.17011	-0.11461	0.04374	0.22591	0.48268	-0.47837	0.69012	0.21535	1.02350
26	0.36660	0.16081	-0.14254	0.03475	0.22552	0.48052	-0.49961	0.68795	0.22736	1.02338
27	0.33813	0.15116	-0.17005	0.02542	0.22572	0.47954	-0.52068	0.68474	0.23881	1.02334
28	0.31017	0.14113	-0.19708	0.01573	0.22583	0.47904	-0.54159	0.68054	0.25147	1.02331
29	0.28277	0.13070	-0.22356	0.00565	0.22610	0.47777	-0.56207	0.67655	0.26435	1.02325
30	0.25614	0.11998	-0.24939	-0.00471	0.22641	0.47632	-0.58230	0.67250	0.27692	1.02318
31	0.23016	0.10901	-0.27459	-0.01531	0.22696	0.47368	-0.60214	0.66883	0.29032	1.02305
32	0.20489	0.09779	-0.29882	-0.02616	0.22777	0.46983	-0.62159	0.66648	0.30199	1.02287
33	0.18064	0.08662	-0.32227	-0.03695	0.22901	0.46871	-0.64059	0.66376	0.30975	1.02281
34	0.15732	0.07559	-0.34480	-0.04761	0.22720	0.47258	-0.65875	0.65805	0.31579	1.02300
35	0.13487	0.06466	-0.36650	-0.05817	0.22644	0.48197	-0.67637	0.64929	0.32097	1.02340
36	0.11331	0.05384	-0.38733	-0.06863	0.22296	0.49251	-0.69312	0.63752	0.32677	1.02390
37	0.09312	0.04328	-0.40685	-0.07884	0.22034	0.50463	-0.70880	0.62430	0.33409	1.02455
38	0.07430	0.03298	-0.42514	-0.08881	0.21735	0.51938	-0.72340	0.61096	0.33867	1.02522
39	0.05756	0.02357	-0.44122	-0.09784	0.21451	0.53123	-0.73626	0.59658	0.34567	1.02584
40	0.04287	0.01479	-0.45542	-0.10637	0.21228	0.54128	-0.74761	0.58512	0.34439	1.02633
41	0.03034	0.00764	-0.46752	-0.11329	0.20314	0.57983	-0.75708	0.58060	0.29938	1.02819
42	0.02023	0.00330	-0.47731	-0.11777	0.17516	0.68619	-0.76383	0.52431	0.20746	1.03342
43	0.01243	0.00150	-0.48484	-0.12019	0.11493	0.86249	-0.76775	0.36020	0.09700	1.04182
44	0.00664	0.0	-0.49043	-0.12067	0.04809	0.85274	-0.76854	-0.12434	0.09262	1.04135
45	0.00224	0.00147	-0.49468	-0.11925	0.31438	-0.34820	-0.76699	-0.67528	0.74018	0.98292
46	0.0	0.00431	-0.49685	-0.11593	0.51589	-2.18979	-0.76110	-0.05546	1.61058	0.85949
47	0.00219	0.01324	-0.49463	-0.11077	0.59442	-2.39759	-0.74979	0.93768	1.69215	0.87582
48	0.00629	0.01747	-0.48833	-0.10379	0.59153	-1.46434	-0.73407	1.09724	1.13607	0.92734
49	0.01412	0.02660	-0.47509	-0.09496	0.43935	-0.91983	-0.71493	1.03719	0.92843	0.95461
50	0.02993	0.03770	-0.46696	-0.08423	0.41179	-0.65689	-0.69344	0.98744	0.85264	0.96699
51	0.04421	0.05053	-0.45218	-0.07183	0.39744	-0.58835	-0.66875	0.97669	0.80164	0.97107
52	0.06344	0.06435	-0.43554	-0.05848	0.38850	-0.52111	-0.64215	0.97080	0.76499	0.97435
53	0.08277	0.07831	-0.41786	-0.04402	0.38292	-0.47979	-0.61120	0.97195	0.73527	0.97643
54	0.10395	0.09433	-0.39721	-0.02951	0.37965	-0.45172	-0.58359	0.97819	0.70693	0.97783
55	0.12432	0.10533	-0.37669	-0.01501	0.37596	-0.42892	-0.55340	0.98597	0.67907	0.97894
56	0.14591	0.12282	-0.35583	-0.00100	0.37310	-0.40823	-0.52342	0.99446	0.65953	0.97996
57	0.16779	0.13776	-0.33468	0.01247	0.37020	-0.38736	-0.49273	1.00220	0.62165	0.98099
58	0.18952	0.15196	-0.31339	0.02532	0.36718	-0.36576	-0.46451	1.00896	0.59233	0.98205
59	0.21196	0.16369	-0.29199	0.03753	0.36417	-0.34434	-0.43581	1.01447	0.56395	0.98311
60	0.23397	0.17560	-0.27072	0.04904	0.36146	-0.32520	-0.40784	1.01981	0.53629	0.98405
61	0.25591	0.18680	-0.24952	0.05987	0.35866	-0.30558	-0.38050	1.02498	0.50700	0.98502
62	0.27736	0.19731	-0.22830	0.07003	0.35514	-0.28102	-0.35372	1.02725	0.47698	0.98622
63	0.29979	0.20718	-0.20711	0.07956	0.35172	-0.25724	-0.32754	1.02693	0.45193	0.98739
64	0.32165	0.21653	-0.18598	0.08865	0.34960	-0.24266	-0.30183	1.02910	0.43005	0.98811
65	0.34345	0.22542	-0.16492	0.09720	0.34807	-0.23224	-0.27653	1.03417	0.40477	0.98862
66	0.36515	0.23359	-0.14400	0.10509	0.34604	-0.21831	-0.25179	1.03751	0.37800	0.98930
67	0.38673	0.24120	-0.12308	0.11244	0.34351	-0.20119	-0.22736	1.03845	0.35164	0.99014

TABLE D.6 (Continued)

68	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
69	0.43647	0.25495	-0.08081	0.12573	0.33833	-0.16625	-0.17914	1.03665	0.30432	0.95186
70	0.45232	0.26115	-0.05969	0.13173	0.33675	-0.15575	-0.15550	1.03734	0.28308	0.95237
71	0.47426	0.26688	-0.03854	0.13726	0.33525	-0.14613	-0.13204	1.03895	0.25921	0.95295
72	0.49621	0.27210	-0.01727	0.14231	0.33331	-0.13288	-0.10968	1.03481	0.23472	0.95359
73	0.51832	0.27685	0.00410	0.14690	0.33127	-0.11943	-0.08549	1.03669	0.21247	0.95415
74	0.54152	0.28118	0.02555	0.15109	0.32984	-0.11096	-0.06243	1.03619	0.19117	0.95461
75	0.56279	0.28506	0.04708	0.15483	0.32843	-0.10090	-0.03544	1.03604	0.16612	0.95506
76	0.58514	0.28834	0.06867	0.15809	0.32677	-0.08552	-0.01659	1.03291	0.13945	0.95582
77	0.60761	0.29111	0.09035	0.16068	0.32301	-0.06568	0.00611	1.02584	0.11527	0.95679
78	0.63037	0.29342	0.11239	0.16291	0.31985	-0.04539	0.02883	1.01629	0.09264	0.95778
79	0.65334	0.29526	0.13459	0.16470	0.31684	-0.02626	0.05148	1.01047	0.07141	0.95872
80	0.67634	0.29666	0.15682	0.16605	0.31405	-0.00985	0.07395	1.00310	0.05329	0.95957
81	0.69944	0.29757	0.17914	0.16693	0.31106	0.01009	0.09629	0.99448	0.02709	1.00049
82	0.72272	0.29792	0.21164	0.16726	0.30722	0.03393	0.11856	0.98280	0.00383	1.00166
83	0.74613	0.29775	0.22427	0.16710	0.30275	0.06140	0.14065	0.96861	-0.01760	1.00300
84	0.76964	0.29706	0.24697	0.16644	0.29791	0.09175	0.16259	0.95283	-0.03745	1.00443
85	0.79320	0.29589	0.26576	0.16530	0.29290	0.12073	0.18406	0.93615	-0.05543	1.00590
86	0.81673	0.29427	0.29251	0.16374	0.28793	0.15003	0.20527	0.91529	-0.07252	1.00732
87	0.84019	0.29218	0.31517	0.16172	0.28267	0.18054	0.22607	0.90096	-0.09116	1.00891
88	0.86321	0.28557	0.33742	0.15919	0.27634	0.21665	0.24616	0.87863	-0.11061	1.01057
89	0.88581	0.28644	0.35926	0.15617	0.26880	0.25871	0.26543	0.85230	-0.12746	1.01262
90	0.90755	0.28294	0.38027	0.15278	0.25976	0.30774	0.28351	0.82078	-0.14311	1.01500
91	0.92851	0.27897	0.40063	0.14895	0.24895	0.36434	0.30043	0.78436	-0.15261	1.01775
92	0.94795	0.27507	0.41936	0.14510	0.23866	0.41579	0.31535	0.75290	-0.15754	1.02025
93	0.96578	0.27153	0.43656	0.14176	0.23116	0.45374	0.32855	0.72631	-0.15322	1.02209
94	0.98096	0.26814	0.45123	0.13848	0.22244	0.49405	0.33555	0.65173	-0.17992	1.02494
95	0.99158	0.26496	0.46149	0.13541	0.20247	0.57906	0.34704	0.60714	-0.23519	1.02815
96	0.99809	0.26174	0.46778	0.13229	0.13310	0.78638	0.35129	0.33378	-0.26925	1.03816
97	1.00000	0.25756	0.46963	0.12025	0.06403	0.82445	0.35166	0.17175	0.11443	1.03599

END OF CALCULATION ON GRID 4 OF 4

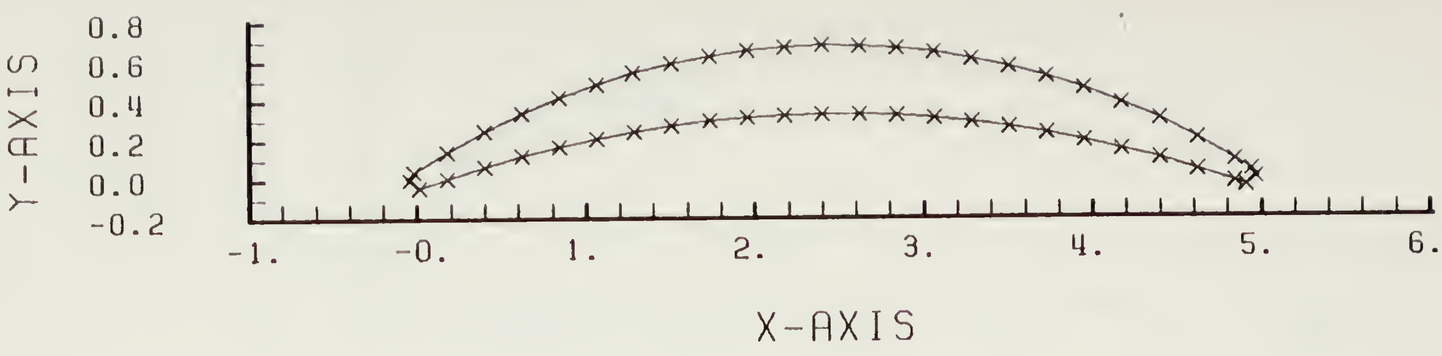


Fig. D.1. Blade Coordinates

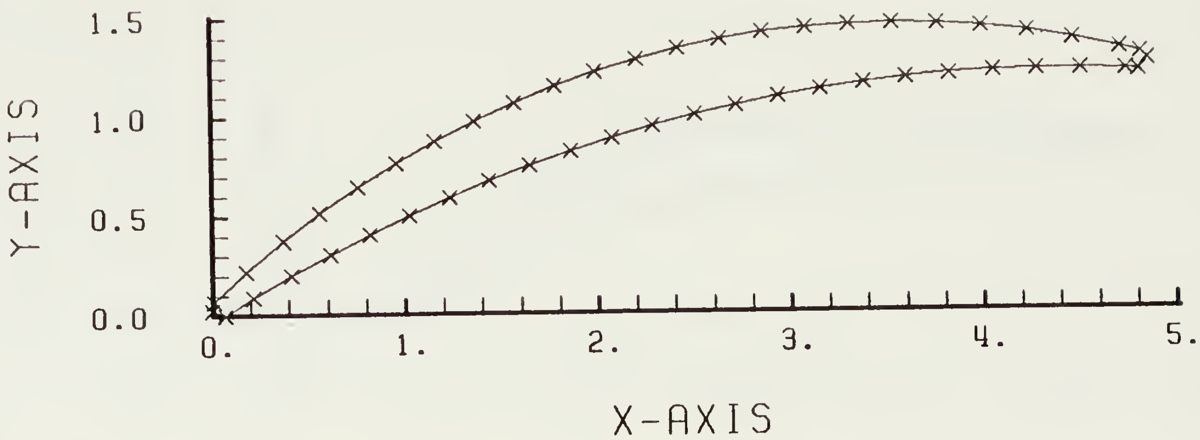


Fig. D.2. Blade Coordinates Translated and Rotated

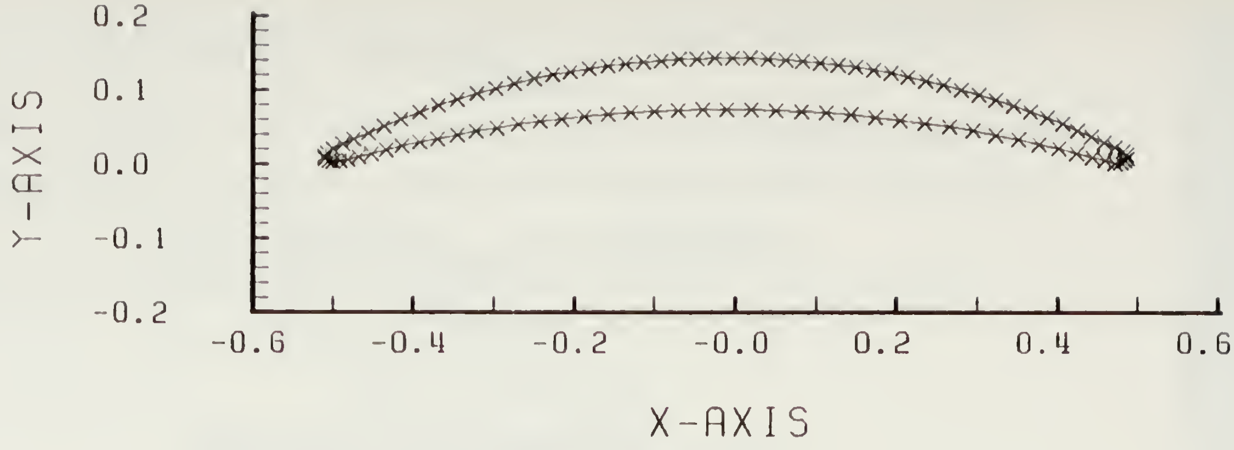


Fig. D.3. Mesh Points on Blade Surface, Horizontal Chord

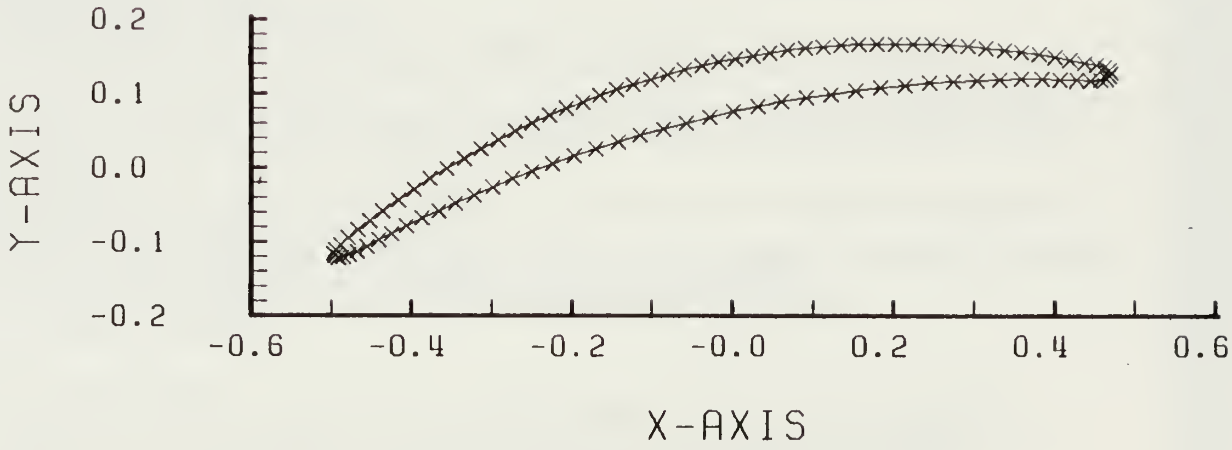


Fig. D.4. Mesh Points on Blade Surface, Chord at Stagger Angle

APPENDIX E

QSONIC PROGRAM LISTING

```
C THIS VERSION WAS COMPILED USING FORTGI. THE SAME CODE COMPILED
C  WITH FORTHX GAVE IDENTICAL RESULTS.
C                                  QSONIC
C
C     COMPUTER PROGRAM FOR CALCULATING THE FULL POTENTIAL QUASI-3D
C
C     TRANSONIC FLOW THROUGH A ROTATING TURBOMACHINERY BLADE ROW.
C
C                  C. A. FARRELL,   J. J. ADAMCZYK
C                  NASA LEWIS RESEARCH CENTER   1981
C        ADAPTED TO THE NAVAL POSTGRADUATE SCHOOL IBM 370/3033
C                                BY
C                LT. WILLIAM D. MOLLOY JR.  18 DEC 81
C
C                          QSONIC EXECUTIVE
C
C                  READS CASE CONTROL INPUT
C                  FOR EACH GRID REQUESTED, CALLS
C                      GEOMETRY SETUP
C                      STREAMCHANNEL DATA SETUP
C                      FLOW SOLVER
C                  CALLS FINAL OUTPUT GENERATOR

      LOGICAL RESTAR,NOFLOW,QUASI3,LEONLY
     1,BUG,BUG2,BUG3,SMOOTH,FINEST,ALLOUT
      INTEGER REMESH,CAMPER
      REAL MINF,LAMDAO,MINF2
      DOUBLE PRECISION CAPK,CAPKP
      COMMON/MESHES/NOZES(10),MS(10),TOLS(10),NOLD(2)
      COMMON/PARAM/RESTAR,NOZIN,BETA1,BETA2,QINF1,CI,CII,GAMMA,MINF,
     1MINF2
     1,DELTA,BETA,TOL,BUG,BUG2,BUG3,IT,GUESS,OVEREL,TIMER,NOWREL,NOTYET
     1,DAMP,SUPREL,S,WAKE,B2OB1,UNDERL,R2OR1,RINF,OMEGA,FLOCO,VAXIAL
     1,ALLOUT,KKMAX
      COMMON/QUASI/R(100,30),B(100,30)
      COMMON/ENTIRE/  X(100,30),Y(100,30),PHI(100,30),DELPSV(100,30)
      COMMON/GEOM2/ZETA(100),ETA(100)
      COMMON/GEOM/NEWNOZ,NEWM,RLE,RTE,A,CHORD,XUPS,XDNS,LAMDAO,CC,CAPK,
     1CAPKP,PI,RNK,VB,KN,NED,BB,DOSURF,RFAC,SOLID,MPLS
     1,STABAC,SLP1,SLP2,SLP3,SLP4,SMOOTH,CHOP,THETT,THETL
     1,FINEST,LEONLY,CAMPER

      DIMENSION TITLE(20)
      NAMELIST/PARAMS/ NOFLOW,RESTAR,REMESH,MS,NOZES,MESH1,MESHN,
     1LAMDAO,CHORD,S,NED,KN,RLE,RTE,THETL,THETT,CAMPER,STABAC,CHOP,
     1SMOOTH,LEONLY,SLP1,SLP2,SLP3,SLP4,MINF,BETA1,BETA2,GAMMA,
     1TOLS,OVEREL,UNDERL,SUPREL,NOWREL,NOTYET,TEGARD,DAMP,CII,IT,
     1ALLOUT,QUASI3,NSTRM,RINF,WAKE,OMEGA,VAXIAL,FLOCO,MINF2
```

```
                                                                         QS000490
      DATA NSTRM,QUASI3,MESH1/1,.FALSE.,1/,REMESH/4/,TEGARD/2./         QS000500
     1,NOFLOW/.FALSE./                                                  QS000510
                                                                         QS000520
      DATA QLEVEL/'9.1'/                                                 QS000530
                                                                         QS000540
      READ(5,3) TITLE                                                    QS000550
3     FORMAT(20A4)                                                       QS000560
      WRITE(6,33) QLEVEL,TITLE                                           QS000570
33    FORMAT(1H1,' QSONIC VERSION 1.4.',A4,2X,21A4//)                    QS000580
                                                                         QS000590
                                                                         QS000600
      READ(5,PARAMS)                                                     QS000610
      WRITE(6,2)                                                         QS000620
2     FORMAT('0     CASE CONTROL INPUT ECHO '/)                          QS000630
      WRITE(6,PARAMS)                                                    QS000640
                                                                         QS000650
                                                                         QS000660
      BETA1=BETA1*PI/180.                                                QS000670
      LAMDA0=LAMDA0*PI/180.                                              QS000680
      BETA2=BETA2*PI/180.                                                QS000690
      MIN=MS(MESH1)                                                      QS000700
      IF(RESTAR)MESH1=REMESH                                             QS000710
      NOZIN=IABS(NOZES(MESH1))                                           QS000720
      IF(QUASI3.AND.B2OB1.EQ.1.)CALL RBIN(NSTRM,LAMDA0)                  QS000730
                                                                         QS000740
                                                                         QS000750
      DO 1 I=MESH1,MESHN                                                 QS000760
      MESH=I                                                             QS000770
      NOLD(2)=NEWM                                                       QS000780
      NOLD(1)=IEXIT                                                      QS000790
      NEWNOZ=NOZES(MESH)                                                 QS000800
      NEWM=MS(MESH)                                                      QS000810
      TOL=TOLS(MESH)                                                     QS000820
      REWIND 23                                                          QS000830
      REWIND 13                                                          QS000840
      CALL WRAPUP(ZETA,ETA,S)                                            QS000850
      IEXIT=2*(NEWNOZ-1)                                                 QS000860
      CALL WHEEL(LAMDA0,NEWM,IEXIT,NOFLOW)                               QS000870
      IF(NOFLOW)STOP                                                     QS000880
      IF(QUASI3) CALL FILLRB(NEWM,IEXIT,RINF,LAMDA0)                     QS000890
      IF(RESTAR.OR.MESH.NE.MESH1)CALL FILPHI(NEWNOZ,NEWM,IEXIT)          QS000900
      IF(SLP1.GE.0.)SLP2=TEGARD                                          QS000910
      CALL USONIC                                                        QS000920
      MYMESH=MESH-MESH1+1                                                QS000930
      MYMAX=MESHN-MESH1+1                                                QS000940
      WRITE(6,4) MYMESH,MYMAX                                            QS000950
4     FORMAT(1H0,40X,' END OF CALCULATION ON GRID',I2,' OF',I2)          QS000960
```

```
1     CONTINUE

      CALL KEEPER
      STOP
      END
      BLOCK DATA

C             INITIALIZE ALL DATA IN COMMON


      LOGICAL RESTAR,LEONLY
     1,BUG,BUG2,BUG3,SMOOTH,FINEST,ALLOUT
      INTEGER CAMPER
      REAL MINF,LAMDAO
      DOUBLE PRECISION CAPK,CAPKP
      COMMON/MESHES/NOZES(10),MS(10),TOLS(10),NOLD(2)
      COMMON/PARAM/RESTAR,NOZIN,BETA1,BETA2,QINF1,CI,CII,GAMMA,MINF,EM
     1,DELTA,BETA,TOL,BUG,BUG2,BUG3,IT,GUESS,OVEREL,TIMER,NOWREL,NOTYET
     1,DAMP,SUPREL,S,WAKE,B2OB1,UNDERL,RADRAT,RADLE,OMEGA,FLOCO,VAXIAL
     1,ALLOUT,KKMAX
      COMMON/QUASI/R(100,30),B(100,30)
      COMMON/ENTIRE/  X(100,30),Y(100,30),PHI(100,30),DELPSV(100,30)
      COMMON/GEOM2/ZETA(100),ETA(100)
      COMMON/GEOM/NEWNOZ,NEWM,RLE,RTE,A,CHORD,XUPS,XDNS,LAMDAO,CC,CAPK,
     1CAPKP,PI,RNK,VB,KN,NED,BB,DOSURF,RFAC,SOLID,MPLS
     1,STABAC,SLP1,SLP2,SLP3,SLP4,SMOOTH,CHOP,THETT,THETL
     1,FINEST,LEONLY,CAMPER

      COMMON/CALVEL/D55(55),PRIORS(14,30),INDEX(100,30),I1DEX(32),
     1FAKEU(100),FAKEV(100),ICOUNT,IDEX,AMY,AMZ

      DATA RADRAT/1./,WAKE,B2OB1/0.,1./,R,B/6000*1./
      DATA RADLE/1./,OVEREL/1.5/,TOL/.001/
     1,PI/3.14159265/,TIMER/1./
     1,OMEGA,FLOCO,VAXIAL/0.,999.,0./
     1,SUPREL/1./,CHOP/.99/,THETT,THETL/0.,0./,CAMPER/6/,EM/10./
      DATA NOTYET/2/,DAMP/1./,STABAC,SLP1,SLP2,SLP3,SLP4,SMOOTH/.999,
     11.,2.,2*1.,.FALSE./,UNDERL/1./,LEONLY/.FALSE./,FINEST/.FALSE./
      DATA A/1.5/,CII/.2/,CI/1./,GUESS/10./,IT/10/,ALLOUT/.FALSE./
      DATA KKMAX/300/
      DATA DELTA,BETA,QINF1,BUG,RESTAR,GAMMA/3*1.,.FALSE.,.FALSE.,1.4/


      DATA INDEX,I1DEX/203*0,1,98*0,2,1,96*0,2,2,4,1,96*0,1,1,1,2497*0,
     1 2,8,2,8,1,1,8,3,3,3,1,1,1,8,2,8,2,8,1,1,8,3,3,3,1,1,1,8,2,8,2,8/
      END
```

```
      SUBROUTINE WHEEL(LAMDAO,NEWM,NEW2M1,NOFLOW)
C     ROTATE X,Y COORDINATES THRU AN ANGLE LAMDAO(RADIANS)

      LOGICAL NOFLOW
      COMMON/ENTIRE/  X(100,30),Y(100,30),PHI(100,30),DELPSV(100,30)
      COMMON/GEOM2/ZETA(100),ETA(100)
      REAL LAMDAO
      COMPLEX H,AI
      DATA AI/(0.,1.)/
      NEW2M=NEW2M1-1
      MM3=NEWM-3
      NNOZ=(NEW2M+1)/2
      NEW2M2=NEW2M1+1
      DO 1 I=1,NEW2M2
      DO 1 J=1,NEWM
      H=CMPLX(X(I,J),Y(I,J))*CEXP(AI*LAMDAO)
      X(I,J)=REAL(H)
1     Y(I,J)=AIMAG(H)
      IF(.NOT.NOFLOW) RETURN
      WRITE(6,10)
10    FORMAT(1H1,30X,' GRID OUTPUT POINTS ON BLADE SURFACE, CHORD ',
     1'AT STAGGER ANGLE'//42X,'  I          X                    Y'/)
      DO 2 I=1,NEW2M2
      I1M=I-1
2     WRITE(6,14) I1M,X(I,NEWM),Y(I,NEWM)
14    FORMAT(41X,I4,2E13.5)
      RETURN
      END
      SUBROUTINE FILPHI(NEWNOZ,NEWM,NEW2M1)
C        BASED ON PHI ARRAY FROM PREVIOUS GRID, INTERPOLATES VALUES
C        TO FILL THE INITIAL PHI ARRAY FOR NEXT, FINER GRID.

      INTEGER OLDNOZ,OLDM
      LOGICAL RESTAR
      COMMON/ENTIRE/  X(100,30),Y(100,30),PHI(100,30),TOPHI(100,30)
      COMMON/MESHES/NOZES(10),MS(10),TOLS(10),NOLD(2)
      COMMON/GEOM2/ ZNEW(100),ENEW(100)
      COMMON/CALVEL/FAKEFI(4,6),FAKFI(4,6),RHOCON,QLIM,EXPO,ROTATN,
     1ROTROT,IM1,IEXIT,PRIORS(14,30),INDEX(100,30),I1DEX(32),FAKEU(75)
     1,FAKEV(75),ICOUNT,IDEX
      COMMON/PARAM/ RESTAR
      DIMENSION OLDE(100),OLDZ(100)
```

```
                                                                        QS001930
      OLDNOZ=NOLD(1)                                                    QS001940
      OLDM=NOLD(2)                                                      QS001950
      NZOLD=OLDNOZ/2+1                                                  QS001960
      INDEX(OLDNOZ-2,3)=0                                               QS001970
      INDEX(OLDNOZ-2,4)=0                                               QS001980
      INDEX(OLDNOZ-2,5)=0                                               QS001990
      INDEX(OLDNOZ-2,6)=0                                               QS002000
      INDEX(OLDNOZ-1,5)=0                                               QS002010
      INDEX(OLDNOZ-1,6)=0                                               QS002020
      INDEX(OLDNOZ,5)=0                                                 QS002030
      INDEX(OLDNOZ,6)=0                                                 QS002040
      INDEX(NZOLD-2,3)=0                                                QS002050
      INDEX(NZOLD-2,4)=0                                                QS002060
      INDEX(NZOLD-2,5)=0                                                QS002070
      INDEX(NZOLD-2,6)=0                                                QS002080
      INDEX(NZOLD-1,5)=0                                                QS002090
      INDEX(NZOLD-1,6)=0                                                QS002100
      INDEX(NZOLD,5)=0                                                  QS002110
      INDEX(NZOLD,6)=0                                                  QS002120
      INDEX(NZOLD+1,4)=0                                                QS002130
      INDEX(NZOLD+1,5)=0                                                QS002140
      INDEX(NZOLD+1,6)=0                                                QS002150
      INDEX(NZOLD+2,3)=0                                                QS002160
      INDEX(NZOLD+2,4)=0                                                QS002170
      INDEX(NZOLD+2,5)=0                                                QS002180
      DO  13 I1=1,NEW2M1                                                QS002190
      DO 13  J1=1,NEWM                                                  QS002200
 13   TOPHI(I1,J1)=0.                                                   QS002210
      REWIND 18                                                         QS002220
      REWIND 8                                                          QS002230
                                                                        QS002240
                                                                        QS002250
      IF(RESTAR)GOTO10                                                  QS002260
      READ(18) OLDE,OLDZ                                                QS002270
      DO 1  I1=1,NEW2M1                                                 QS002280
      DO 2  I2=1,OLDNOZ                                                 QS002290
      IF(OLDE(I2).GT.ENEW(I1))  GOTO3                                   QS002300
 2    CONTINUE                                                          QS002310
      I2=OLDNOZ                                                         QS002320
 3    DO 1  I3=1,NEWM                                                   QS002330
      DO 5  I4=1,OLDM                                                   QS002340
      IF(OLDZ(I4).GT.ZNEW(I3))GOTO6                                     QS002350
 5    CONTINUE                                                          QS002360
      I4=OLDM                                                           QS002370
 6    FACE=(ENEW(I1)-OLDE(I2-1))/(OLDE(I2)-OLDE(I2-1))                  QS002380
      TERP3=                                                            QS002390
     1PHI(I2-1,I4)+(PHI(I2,I4)-PHI(I2-1,I4))*FACE                       QS002400
```

```
      TERP1=                                                            QS002410
     1PHI(I2-1,I4-1)+(PHI(I2,I4-1)-PHI(I2-1,I4-1))*FACE                 QS002420
      BOP=(TERP3-TERP1)/(OLDZ(I4)-OLDZ(I4-1))*(ZNEW(I3)-                QS002430
     1OLDZ(I4-1))+TERP1                                                 QS002440
1     TOPHI(I1,I3)=BOP                                                  QS002450
                                                                        QS002460
                                                                        QS002470
      DO 7 I1=1,NEW2M1                                                  QS002480
      DO 7 I3=1,NEWM                                                    QS002490
7     PHI(I1,I3)=TOPHI(I1,I3)                                           QS002500
                                                                        QS002510
                                                                        QS002520
22    FORMAT(4I6,4E13.5)                                                QS002530
4     FORMAT(1H ,8E13.5)                                                QS002540
      WRITE(8,11) PHI                                                   QS002550
      DO  1313 I1=1,NEW2M1                                              QS002560
      DO 1313 J1=1,NEWM                                                 QS002570
1313  TOPHI(I1,J1)=0.                                                   QS002580
      RETURN                                                            QS002590
                                                                        QS002600
C       IF RESTART, READ PHI FROM THE RESTART FILE                      QS002610
10    READ(9,11) PHI                                                    QS002620
11    FORMAT(6E13.5)                                                    QS002630
      RESTAR=.FALSE.                                                    QS002640
      REWIND 9                                                          QS002650
12    RETURN                                                            QS002660
      END                                                               QS002670
      SUBROUTINE RBIN(NSTRM,LAMDAO)                                     QS002680
                                                                        QS002690
C   FOR QUASI3D CASES, READS UNIT 2 WITH DISTRIBUTIONS OF SPANWISE RADIUSQS002700
C    AND CHANNEL THICKNESS.  FORMAT IS THE SAME AS PROGRAM TSONIC.      QS002710
                                                                        QS002720
      REAL LAMDAO                                                       QS002730
      COMMON/MERIDL/ ZMSP(50,2),THSP(50,2),RMSP(50),                    QS002740
     1BESP(50),RM(50),NRSP,NSP(2),RTE(2),RLE(2),STGRF,CHO,CNBL,DM       QS002750
      DIMENSION DUM1(50),R(2)                                           QS002760
      REWIND 2                                                          QS002770
      ISTRM=IABS(NSTRM)                                                 QS002780
      DO 1 I=1,ISTRM                                                    QS002790
      READ(2,3)                                                         QS002800
      READ(2,3)                                                         QS002810
      READ(2,6) A1,A2,CHO,STGRF                                         QS002820
      READ(2,3)                                                         QS002830
3     FORMAT(1H )                                                       QS002840
      READ(2,4) NBL,NRSP,I1,I2,I3                                       QS002850
      CNBL=FLOAT(NBL)                                                   QS002860
4     FORMAT(30X,I5,4I5)                                                QS002870
      DO 10 J=1,2                                                       QS002880
```

```
      READ(2,5) RI,RO,SPLNO1
      ISPL1=SPLNO1
C     WRITE(6,4) I,NRSP,J,ISPL1
      NSP(J)=ISPL1
      RTE(J)=RO
      RLE(J)=RI
5     FORMAT(2F10.5,20X,F10.5)
6     FORMAT(8F10.6)
      READ(2,6) (ZMSP(IA,J),IA=1,ISPL1)
10    READ(2,6) (THSP(IA,J),IA=1,ISPL1)

C    READ X VALUES

      READ(2,6) (RM(IA),IA=1,NRSP)

C    READ CORRESPONDING SPANWISE RADIUS VALUES.

      READ(2,6) (RMSP(IA),IA=1,NRSP)

C    READ STREAMCHANNEL THICKNESS VALUES.

      READ(2,6) (BESP(IA),IA=1,NRSP)

      IF(I1.EQ.1)READ(2,6) (DUM1(IA),IA=1,NRSP)
      IF(I2.EQ.1)READ(2,6) (DUM1(IA),IA=1,NRSP)
1     READ(2,4) I4
      IF(NSTRM.LT.0) RETURN

C     TRANSLATE ORIGIN OF X VALUES TO MIDCHORD AND NORMALIZE RADIUS AND
C     THICKNESS TO THE AERODYNAMIC CHORD.

      DO 7 I=1,NRSP
      RM(I)=(RM(I)-CHO/2.)/CHO*COS(LAMDAO)
      RMSP(I)=RMSP(I)/CHO*COS(LAMDAO)
7     BESP(I)=BESP(I)/CHO*COS(LAMDAO)


      RETURN
      END
      SUBROUTINE FILLRB(NEWM,NEW2M1,RADLE,STAG)

C INTERPOLATES ON THE INPUT (OR ASSUMED LINEAR) DISTRIBUTIONS OF RADIUS
C AND THICKNESS TO FILL ARRAYS OF SPANWISE POSITION AND STREAMCHANNEL
C THICKNESS AT ALL GRID POINTS.

C             IF RADLE=1.,  RADIUS IS ASSUMED CONSTANT
```

```
      COMMON/QUASI/R(100,30),B(100,30)                                  QS003370
      COMMON/MERIDL/ ZMSP(50,2),THSP(50,2),RMSP(50),                    QS003380
     1BESP(50),RM(50),NRSP,NSP(2),RTE(2),RLE(2),STGRF,CHO,CNBL,DUMM     QS003390
      COMMON/ENTIRE/  X(100,30),Y(100,30),PHI(100,30),DELPSV(100,30)    QS003400
      COMMON/PARAM/ RESTAR,NOZIN,BRM(17),USELER,BR(6),B2OB1,UNDERL,R2OR1QS003410
      NEW2M2=NEW2M1+1                                                   QS003420
      N=NRSP                                                            QS003430
      CO=COS(STAG)/2.                                                   QS003440
                                                                        QS003450
C             NOZIN=NEW2M1/2 ON THE FIRST PASS ONLY                     QS003460
                                                                        QS003470
      IF(NOZIN.EQ.NEW2M1/2)FIXR=RADLE                                   QS003480
      IF(NOZIN.EQ.NEW2M1/2)B21SAV=B2OB1                                 QS003490
      IF(RADLE.NE.1..AND.R2OR1.EQ.1.)R2OR1=RMSP(NRSP)/RMSP(1)           QS003500
      IF(B2OB1.EQ.1.)B2OB1=BESP(NRSP)/BESP(1)                           QS003510
                                                                        QS003520
                                                                        QS003530
                                                                        QS003540
      IF(B21SAV.NE.1..OR.NOZIN.NE.NEW2M1/2.OR.USELER.EQ.0..OR.RADLE.EQ.1QS003550
     *.)GOTO15                                                          QS003560
                                                                        QS003570
C          FIND L.E. OF BLADE (RM+CO=0.)                                QS003580
                                                                        QS003590
      DO 13 I5=1,NRSP                                                   QS003600
      IF(RM(I5)+CO.GT.0.)GOTO14                                         QS003610
 13   CONTINUE                                                          QS003620
      I5=NRSP                                                           QS003630
                                                                        QS003640
C     CALCULATE SPANWISE POSITION AT L.E. (FIXR)  FROM THE GIVEN RADIUS QS003650
C     DISTRIBUTION.                                                     QS003660
 14   FIXR=                                                             QS003670
     1RMSP(I5-1)-(RMSP(I5)-RMSP(I5-1))*(CO+RM(I5-1))/(RM(I5)-RM(I5-1))  QS003680
                                                                        QS003690
                                                                        QS003700
 15   DO 1 I1=1,NEW2M2                                                  QS003710
      DO 1 I3=1,NEWM                                                    QS003720
      IF(B21SAV.NE.1.)GOTO12                                            QS003730
      DO 2 I2=1,NRSP                                                    QS003740
      IF(RM(I2).GT.X(I1,I3))GOTO3                                       QS003750
 2    CONTINUE                                                          QS003760
      I2=NRSP                                                           QS003770
 3    IF(I2.EQ.1)I2=2                                                   QS003780
      FACE=(X(I1,I3)-RM(I2-1))/(RM(I2)-RM(I2-1))                        QS003790
      TERPR=RMSP(I2-1)+(RMSP(I2)-RMSP(I2-1))*FACE                       QS003800
C     IF(RM(NRSP).LT.X(I1,I3))TERPR=RMSP(NRSP)                          QS003810
C     IF(RM(1).GT.X(I1,I3))TERPR=RMSP(1)                                QS003820
      TERPB=BESP(I2-1)+(BESP(I2)-BESP(I2-1))*FACE                       QS003830
      IF(RADLE.NE.1.)R(I1,I3)=TERPR                                     QS003840
```

```
      B(I1,I3)=TERPB/BESP(1)
      GOTO10

C  IF (B21SAV.NE.1), A LINEAR DISTRIBUTION OF THICKNESS IS ASSUMED OVER
C   3 CHORD LENGTHS.

12    B(I1,I3)=1.+(B20B1-1.)*(X(I1,I3)+1.5)/3.
      IF(RADLE.NE.1.)FIXR=(1.+(R2OR1-1.)*(1.5-CO)/3.)*RADLE
      IF(X(I1,I3).LT.-1.5)B(I1,I3)=1.
      IF(X(I1,I3).GT.1.5)B(I1,I3)=B20B1
      IF(RADLE.NE.1.)R(I1,I3)=(1.+(R2OR1-1.)*(X(I1,I3)+1.5)/3.)*RADLE
      IF(X(I1,I3).LT.-1.5)R(I1,I3)=RADLE
      IF(X(I1,I3).GT.1.5)R(I1,I3)=R2OR1*RADLE


C  SCALE THE TANGENTIAL COORDINATE Y (R*THETA), TO THE LOCAL RADIUS.

C10   Y(I1,I3)=Y(I1,I3)*R(I1,I3)/FIXR
10    CONTINUE
1     CONTINUE
      USELER=FIXR
      RETURN
4     FORMAT(2I5,6E10.4)
      END

      SUBROUTINE USONIC


C                       FULL POTENTIAL FLOW SOLVER
C                         FOR CASCADE GEOMETRIES

C       ETA = COMPUTATIONAL COORDINATE THAT  IS CONSTANT ON LINES
C             RADIATING FROM BLADE .
C       ZETA= COMPUTATIONAL COORDINATE THAT IS CONSTANT ON LINES
C             SURROUNDING THE BLADE.
C             (THESE ARE REVERSED FROM INTERPOLATION GRID GENERATOR)


C     DO (INPUT SPECIFICATION)
C     DO (INITIALIZATION OF FIELD VARIABLES)
C     RELAXD= .FALSE.
C     DO UNTIL (RELAXD)
C        KK=KK+1
C        KKK=KKK+1
C        IF(KK.GT.NOWREL) OVEREL=RELSAV
C        IF(KK.GT.NOTYET) SUPREL=SUPSAV
```

```
C         DO UNTIL (EXIT)
C            I=I+1
C            IM1= I-1
C            IF(IM1.EQ.0) IM1=2
C            DO (AXIAL LOCATION INDICATORS)
C            DO UNTIL (TOP)
C               J=J+1
C               JM1=J-1
C               IF(JM1.EQ.0) JM1=2
C               DO (VERTICAL LOCATION INDICATORS)
C               DO (BOUNDARY CONDITION SWITCHES)
C               DO (GEOMETRY ADVANCE)
C               DO (FIELD GRADIENTS)
C               DO (VELOCITIES AND DENSITIES)
C               DO (SUPERSONIC CORRECTION)
C               DO ( T'S,Q'S AND RESIDUALS)
C               DO ( DELPHI COEFFICIENTS AND TRANSPOSED TERMS)
C            END
C            DO (FORWARD ELIMINATION)
C            IF(I.NE.1)
C           1DO (BACK SUBSTITUTION)
C            J=0
C         END
C         DO (UPDATE OF FIELD VARIABLES)
C         DO (CONVERGENCE TESTS)
C         I=0
C      END
C      DO (SURFACE FLOW CALCULATION FOR FINISHED GRID)
C      RETURN
C      ENTRY KEEPER
C      DO (OUTPUT OF PHI AND CALCULATION OF FINAL VELOCITY FIELD)
C      RETURN


      LOGICAL INLET,BLADE,EXIT,BOTTOM,TOP,
     1  RELAXD,SETTLE,BUG,  BUG3,BUG2
      LOGICAL DOSURF,SMOOTH,FINEST,RESTAR,ALLOUT
      REAL LAB,LAD,MINF,LENGTH,JACOB,LAMDAO
      REAL MACHA,MACHB,MINF2
      REAL MACH(8)
      INTEGER FIRSTJ
      DOUBLE PRECISION CAPK,CAPKP
      COMMON/PARAM/RESTAR,NOZIN,BETA1,BETA2,QINF1,CI,CII,GAMMA,MINF,EM
     1,DELTA,BETA,TOL,BUG,BUG2,BUG3,IT,GUESS,OVEREL,FIXR,NOWREL,NOTYET
     1,DAMP,SUPREL,S,WAKE,B2OB1,UNDERL,RADRAT,RADLE,OMEGA,FLOCO,VAXIAL,
     1ALLOUT,KKMAX
      COMMON/QUASI/ RADIUS(100,30),HEIGHT(100,30)
      COMMON/ENTIRE/  X(100,30),Y(100,30),PHI(100,30),DELPSV(100,30)
```

```
      COMMON/GEOM2/ZETA(100),ETA(100)
      COMMON/CROSS/ ZMACH(100,30)
      COMMON/GEOM/NOZ,M,RLE,RTE,A,CHORD,XUPS,XDNS,LAMDAO,CC,CAPK,
     1CAPKP,PI
     1,RNK,VB,KN,NED,BB,DOSURF,RFAC,SOLID,MPLS
     1,STABAC,SLP1,SLP2,SLP3,SLP4,SMOOTH,CHOP,THETT,THETL
     1,FINEST
      COMMON/CALVEL/FAKEFI(4,6),FAKFI(4,6),RHOCON,QLIM,EXPO,ROTATN,
     1ROTROT,IM1,IEXIT,PRIORS(14,30),INDEX(100,30),I1DEX(32),FAKEU(100)
     1,FAKEV(100),ICOUNT,IDEX,AMY,AMZ
      COMMON/VELOUT/D(100),E(100),F(100),DELPHI(100),TENOLF(100,30),
     1DUMBX(100,30),DUMBY(100,30),BOPR,FADBOP,XOCX,KK
      DIMENSION RHOSS(8), FI1(8),FI2(3),FI3(3),FI9(8),SPAN(8),
     1EMACH(100,30)
     2,COSX(8),COSY(8),LENGTH(8),DEDX(8),DZDX(8),DEDY(8),
     3DZDY(8),T(8),DPHIDZ(8),DPHIDE(8),U(8),V(8),UN(8),RHO(8),
     4RHOUL(8),ONOFF(8),DELPM1(3)
     5,HITE(8)
      NAMELIST/ABSLUT/MINF,MINF2,QINF2,ABETA1,ABETA2,AQINF1,AQINF2,AMINF
     1,AEM,ROTATN
      NAMELIST/PARAMS/    IEXIT,NOZ,M,BETA1,BETA2,LAMDAO
     1,S,CHORD,RLE,RTE,NED,KN
     1,STABAC,SLP1,SLP2,SLP3,SLP4,CHOP,THETT,THETL
     1,QINF1,CI,CII,GAMMA,MINF,EM,DELTA,BETA,WAKE,B2OB1,RADRAT
     1,OMEGA,FLOCO,VAXIAL
     1,TOL,BUG,IT,GUESS,OVEREL,  SUPREL,NOWREL,NOTYET,DAMP,
     1 SMOOTH,FINEST,BUG,BUG2,BUG3
      NAMELIST/YTESD/ KK,AIJ,AIJM1,AIJP1, TRANSP,I,J,CIRCO
      NAMELIST/CONST/CIRCLN,MINF2,B2OB1,R2OR1,RINF,RATLE
      DATA AQINF1/1./,AVGFAC,TEST/1.,1./


      COMMON/HIBALL/ SUPERG(46,30,100)

      XDIF(A,B,C,D)=.5*(A+B-C-D)






C     DO (INPUT SPECIFICATION)

C     PROCEDURE (INPUT SPECIFICATION)

      IF(NOZ-1.NE.NOZIN) GOTO 201
C     IF(NOZ-1.EQ.NOZIN) THEN
```

```
      RELSAV=OVEREL
      UNDSAV=UNDERL
      SUPSAV=SUPREL
      SHIFTM=ABS(CI)
      IF(RADRAT.EQ.1.)RADLE=1.
      IF(RADRAT.EQ.1.)FIXR=1.
      IF(SHIFTM.EQ.0.)SHIFTM=1.
      IF(FLOCO.EQ.999..AND.OMEGA.NE.0.)
     1FLOCO=VAXIAL/OMEGA/RADLE
      IF(FIXR.LT.1.E-06)FIXR=1.
      ROTATN=COS(BETA1+LAMDA0)/FLOCO
      IF(OMEGA.EQ.0..AND.FLOCO.EQ.999.)ROTATN=0.
      ROTROT=ROTATN**2
      BEETA1=(BETA1+LAMDA0)
      BEETA2=(BETA2+LAMDA0)

C     DO (EXIT MACH NUMBER ITERATION)

C     PROCEDURE (EXIT MACH NUMBER ITERATION)

      FAB=(GAMMA-1.)/2.
      ROTFAC=ROTROT*(RADRAT**2-1.)
      IF(EM.NE.10.) GOTO205
C     IF(EM.EQ.10.) THEN
      P1OP2=1./(RADRAT-WAKE/S)
      SETTLE=.FALSE.
      IF(MINF.GT.0.)EM=MINF*.8
      IF(MINF.LT.0.)EM=1.0+ABS(MINF)
      MINF=ABS(MINF)
      FAC1=1./(1.+FAB*MINF*MINF*(1.+ROTFAC))
      FAC1=FAC1**((GAMMA+1.)/4./FAB)*COS(BEETA1)/COS(BEETA2)/B2OB1
     1*P1OP2*MINF
208   FAC2=1./(1.+FAB*EM*EM)
      FAC3=FAC2**((GAMMA+1.)/4./FAB)
      EFF=EM*FAC3-FAC1
      DFDM=FAC3*(1.-FAC2*EM*EM*(GAMMA+1.)/2.)
      DM=-EFF/DFDM
      SETTLE=ABS(DM)/EM.LT..001
      EM=EM+DM
      IF(.NOT.SETTLE)GOTO208
C     END
205   MINF2=EM
      MINF=ABS(MINF)
      QINF2=SQRT((1.+ROTFAC+1./FAB/MINF/MINF)/(1.+1./FAB/EM/EM))
      AQINF2=QINF2
      ABETA2=BEETA2*180./PI
```

```
      ABETA1=BEETA1*180./PI
      IF(ROTATN.EQ.0.) GOTO210
C     IF(ROTATN.NE.0.) THEN
      SINBET=SIN(BEETA1)+ROTATN
      COSBET =COS(BEETA1)
      ABETA1=ATAN2(SINBET,COSBET)*180./PI
      SINBET=QINF2*SIN(BEETA2)+ROTATN*RADRAT
      COSBET=QINF2*COS(BEETA2)
      ABETA2=ATAN2(SINBET,COSBET)*180./PI
      AQINF1=COS(BEETA1)/COS(PI/180.*ABETA1)
      AQINF2=QINF2*COS(BEETA2)/COS(PI/180.*ABETA2)
      AMINF=MINF*COS(BEETA1)/COS(PI/180.*ABETA1)
      AEM=EM*COS(BEETA2)/COS(ABETA2*PI/180.)
      WRITE(6,779)
779   FORMAT('1ROTATION EFFECTS INCLUDED,ABSOLUTE AND RELATIVE VELOCITY'
     1,' TRIANGLES HAVE - ')
      WRITE(6,ABSLUT)
      BETA1=ABETA1*PI/180.-LAMDAO
      BETA2=ABETA2*PI/180.-LAMDAO
C     END
210   P1OP2=1./RADRAT
      CIRCO=RADLE/FIXR*S*(AQINF1*SIN(LAMDAO+BETA1)-AQINF2*SIN(LAMDAO+
     1BETA2)/P1OP2)
      CIRCOO=CIRCO
      IF(CIRCO.EQ.0.)CIRCOO=1.
      CIRCLN=CIRCO
      R2OR1=RADRAT
      RINF=RADLE
      RATLE=FIXR
      WRITE(6,780)
780   FORMAT('1CALCULATED FLOW PARAMETERS')
      WRITE(6,CONST)
C      END
C     END


201   IF(NOZ-1.NE.NOZIN)SUPSAV=SUPSAV-CII
      IF(SUPSAV.LT..5)SUPSAV=.5
      OVEREL=1.
      UNDERL=1.
      SUPREL=1.
      NZZ=2*NOZ-2
      KKK=0
      IEXIT=NZZ
      I67=M-14+1
      I67=MAXO(I67,1)
2     FORMAT(6E13.5)
```

```
      KK=0
      M3=M-3
      ITIEX=IEXIT-1
      WRITE(6,777) M3,ITIEX,SUPSAV
777   FORMAT(1H1,12X,
     1'RELAXATION BEGINS ON GRID OF ',I3,' SURFACE CONTOURS ',
     1'INTERSECTED BY ',I3,' RADIATING LINES'/1H0,30X,'SUPERSONIC ',
     1'RELAXATION ',
     1'PARAMETER, SUPREL= ',E13.5)
      WRITE(6,778)
778   FORMAT(1H0,3X,'ITERATION    AVERAGE        RESIDUAL     ',
     1' MAX MACH       ',
     1' CALCULATED   RELATIVE CIRC     SUBSONIC     SUPERSONIC    '/6X,
     1'COUNT    PHI CORRECTN    AT T. E.     ON BLADE      CIRCULATION',
     1'       ERROR      ',
     1'    RELAX. FAC.  RELAX. FAC.'/)
C      IF(WAKE.EQ.0.) GOTO212
CC     IF(WAKE.NE.0.) THEN
C      XMAX=0.
C      DO 101 I1=1,IEXIT
C      IF(X(I1,M).GT.XMAX)XMAX=X(I1,M)
C      IF(X(I1,M).GT.XMAX)ITE=I1
C101   CONTINUE
C      X44=.95*X(ITE,M)
C      X12=(X(2,4)-X44)*SLP3
C      MO2=M/2
C      DO 109 I105=1,IEXIT
C      IF(ABS(X(I105,MO2)-X12-X44).LE.1.E-02) GOTO1091
C109   CONTINUE
C1091  CONTINUE
C      S105=RADLE/FIXR*S*RADIUS(I105,MO2)/RADLE
C      BDELT=WAKE/S105*SLP4
C      DO 119 I=1,IEXIT
C      DO 118 J=1,M
C      IF(X(I,J).GT.X44)TERPIT=AMIN1((X(I,J)-X44)/X12,1.)
C      IF(X(I,J).GT.X44)HEIGHT(I,J)=HEIGHT(I,J)*(1.-TERPIT*BDELT)
C118   CONTINUE
C119   CONTINUE
C     END
C      END


C      DO (INITIALIZATION OF FIELD VARIABLES)

C      PROCEDURE (INITIALIZATION OF FIELD VARIABLES)
```

```
212   COBB=COS(LAMDAO+BETA1)*AQINF1*RADLE                                QS006730
      COSB=COS(LAMDAO+BETA1)*AQINF1                                      QS006740
      SIBB = SIN(LAMDAO+BETA1)*AQINF1*RADLE                              QS006750
      SINB=SIN(LAMDAO+BETA1)*AQINF1                                      QS006760
      IF(RESTAR.OR.NOZ-1.NE.NOZIN)GOTO219                                QS006770
      IEXP1=IEXIT+1                                                      QS006780
      BBLR= BEETA1+BEETA2+LAMDAO+ROTATN                                  QS006790
      DO 135 I=1,IEXP1                                                   QS006800
      DO 134  J=1,M                                                      QS006810
      PHI(I,J)=COSB*X(I,J)+SINB*Y(I,J)                                   QS006820
      IF(ROTATN.NE.0.)PHI(I,J)=PHI(I,J)*RADLE                            QS006830
      RDDDD=RADLE/HEIGHT(I,J)/RADIUS(I,J)                                QS006840
      IF(BBLR.EQ.0.)PHI(I,J)=PHI(I,J)*RDDDD                              QS006850
134   CONTINUE                                                           QS006860
135   CONTINUE                                                           QS006870
219   NOZM1=NOZ-1                                                        QS006880
      NOZP1=NOZ+1                                                        QS006890
      DO 141 I=NOZM1,NOZP1                                               QS006900
      DO 140 J=3,5                                                       QS006910
      PHI(I,J)=COSB*X(I,J)+SINB*Y(I,J)                                   QS006920
      IF(ROTATN.NE.0.)PHI(I,J)=PHI(I,J)*RADLE                            QS006930
      RDDDD=RADLE/HEIGHT(I,J)/RADIUS(I,J)                                QS006940
      IF(BBLR.EQ.0.)PHI(I,J)=PHI(I,J)*RDDDD                              QS006950
140   CONTINUE                                                           QS006960
141   CONTINUE                                                           QS006970
      DO 153  J=1,6                                                      QS006980
      DO 152 I1=1,4                                                      QS006990
      I10=IEXIT+I1-3                                                     QS007000
      IF(J.LE.5.AND.J.GT.2.AND.                                          QS007010
     1(NOZ-1.NE.NOZIN.OR.RESTAR)                                         QS007020
     1.AND.I1.NE.4)PHI(I1,J)=(COSB*X(I1,J)+SINB*Y(I1,J))                 QS007030
     1                                                                   QS007040
      IF(ROTATN.NE.0.)PHI(I1,J)=PHI(I1,J)*RADLE                          QS007050
      RDDDD=RADLE/HEIGHT(I1,J)/RADIUS(I1,J)                              QS007060
      IF(BBLR.EQ.0.)PHI(I1,J)=PHI(I1,J)*RDDDD                            QS007070
      IF(J.LE.5.AND.J.GT.2.AND.                                          QS007080
     1(NOZ-1.NE.NOZIN.OR.RESTAR)                                         QS007090
     1.AND.I10.GT.IEXIT-2)PHI(I10,J)=(COSB*X(I10,J)+SINB*Y(I10,J))       QS007100
     1                                                                   QS007110
      IF(ROTATN.NE.0.)PHI(I10,J)=PHI(I10,J)*RADLE                        QS007120
      RDDDD=RADLE/HEIGHT(I10,J)/RADIUS(I10,J)                            QS007130
      IF(BBLR.EQ.0.)PHI(I10,J)=PHI(I10,J)*RDDDD                          QS007140
152   CONTINUE                                                           QS007150
153   CONTINUE                                                           QS007160
      DO 161  J=1,M                                                      QS007170
      PHI(1,J)=                                                          QS007180
     1 PHI(IEXIT-1,J)-RADLE/FIXR*S*(AQINF1*SIN(LAMDAO+BETA1)-AQINF2*SIN( QS007190
     1LAMDAO+BETA2)/PIOP2)                                               QS007200
```

```
161   PHI(IEXIT+1,J)=PHI(3,J)+                                           QS007210
     1   RADLE/FIXR*S*(AQINF1*SIN(LAMDAO+BETA1)-AQINF2*SIN(LAMDAO+       QS007220
     1BETA2)/P1OP2)                                                      QS007230
      I=0                                                                QS007240
      J=0                                                                QS007250
      RHOCON=(GAMMA-1.)/2.*MINF*MINF                                     QS007260
      EXPO= 1./(GAMMA-1.)                                                QS007270
      QLIM=1.+1./RHOCON                                                  QS007280
      BMZ=1./MINF/MINF                                                   QS007290
      BMY=(GAMMA-2.)/2.                                                  QS007300
      AMZ=.5/BMZ                                                         QS007310
      BMX=BMY*AMZ/2.                                                     QS007320
      AMY=-BMX/BMZ                                                       QS007330
      BIGK=RADLE/FIXR*COS(BEETA1)                                        QS007340
      UOOUT=AQINF2*COS(ABETA2*PI/180.)                                   QS007350
      DPHTHO=AQINF2*SIN(ABETA2*PI/180.)*RADRAT*RADLE/FIXR                QS007360
      UOIN=AQINF1*COS(ABETA1*PI/180.)                                    QS007370
      DPHTHI=AQINF1*SIN(ABETA1*PI/180.)*RADLE/FIXR                       QS007380
      INDEX(NOZ-2,3)=3                                                   QS007390
      INDEX(NOZ-2,4)=3                                                   QS007400
      INDEX(NOZ-2,5)=3                                                   QS007410
      INDEX(NOZ-2,6)=1                                                   QS007420
      INDEX(NOZ-1,5)=2                                                   QS007430
      INDEX(NOZ-1,6)=1                                                   QS007440
      INDEX(NOZ,5)=2                                                     QS007450
      INDEX(NOZ,6)=1                                                     QS007460
      INDEX(NOZ+1,4)=2                                                   QS007470
      INDEX(NOZ+1,5)=4                                                   QS007480
      INDEX(NOZ+1,6)=1                                                   QS007490
      INDEX(NOZ+2,3)=1                                                   QS007500
      INDEX(NOZ+2,4)=1                                                   QS007510
      INDEX(NOZ+2,5)=1                                                   QS007520
      INDEX(IEXIT-2,3)=3                                                 QS007530
      INDEX(IEXIT-2,4)=3                                                 QS007540
      INDEX(IEXIT-2,5)=3                                                 QS007550
      INDEX(IEXIT-2,6)=1                                                 QS007560
      INDEX(IEXIT-1,5)=2                                                 QS007570
      INDEX(IEXIT-1,6)=1                                                 QS007580
      INDEX(IEXIT,5)=2                                                   QS007590
      INDEX(IEXIT,6)=1                                                   QS007600
                                                                         QS007610
                                                                         QS007620
      IF(B2OB1*RADLE.EQ.1.)GOTO 2691                                     QS007630
C   FOR QUASI - 3D CASES, ADJUST CHANNEL AREA AT FARFIELD ELEMENTS WHERE QS007640
C   IT DROPS BELOW SONIC THROAT AREA BASED ON THE INPUT DISTRIBUTIONS.   QS007650
                                                                         QS007660
      DO 162 I1=1,IEXP1                                                  QS007670
      DO 162 J1=1,M                                                      QS007680
```

```
      IF(INDEX(I1,J1).EQ.0)GOTO162                                       QS007690
      ROTFAC=ROTROT*((RADIUS(I1,J1)/RADLE)**2-1.)+1.                     QS007700
      IF(I1.LE.NOZ-3.OR.I1.GE.NOZ+3)GOTO1622                             QS007710
      ASTAR=MINF*COS(BEETA1)/(ROTFAC*MINF*MINF*FAB+1.)**((GAMMA+1.)/4.   QS007720
     1/FAB)*RADLE*((1.+MINF*MINF*SIN(BEETA1)**2)*FAB+1.)**((GAMMA+1.)/4.QS007730
     11/FAB)                                                             QS007740
      WMACH=MINF                                                         QS007750
      GOTO1623                                                           QS007760
 1622 ASTAR=EM*COS(BEETA2)/(ROTFAC*EM*EM*FAB+1.)**((GAMMA+1.)/4.         QS007770
     1/FAB)*RADLE*((1.+EM*EM*SIN(BEETA2)**2)*FAB+1.)**((GAMMA+1.)/4.     QS007780
     11/FAB)*RADRAT*B2OB1                                                QS007790
      WMACH=EM                                                           QS007800
 1623 IF(ASTAR.LE.RADIUS(I1,J1)*HEIGHT(I1,J1))GOTO162                    QS007810
      WRITE(6,1666) I1,J1,X(I1,J1),WMACH,ASTAR                           QS007820
 1666 FORMAT('0QUASI-3D CHANNEL CROSSECTION AT BOUNDARY ELEMENT I = ',I3QS007830
     1,' J = ',I3,' X = ',E13.5,' FALLS BELOW SONIC THROAT AREA'/        QS007840
     1' BASED ON MACH= ',F7.4, ' AT FAR FIELD STATION.'                  QS007850
     1,' PROCEEDING WITH AREA = 1.01 * THROAT = 1.01 * ',E12.5)          QS007860
                                                                         QS007870
C     RRR=ASTAR/HEIGHT(I1,J1)                                            QS007880
C     IF(RADLE.NE.1..AND.B2OB1.NE.1.)RADIUS(I1,J1)=(RRR+RADIUS(I1,J1))/2QS007890
C     IF(RADLE.NE.1..AND.B2OB1.NE.1.)HEIGHT(I1,J1)=ASTAR*1.01/RADIUS(I1,QS007900
C     IF(B2OB1.NE.1..AND.RADLE.EQ.1.)HEIGHT(I1,J1)=1.01*ASTAR            QS007910
C     IF(B2OB1.EQ.1..AND.RADLE.NE.1.)RADIUS(I1,J1)=ASTAR*1.01            QS007920
      HEIGHT(I1,J1)=ASTAR*1.01/RADIUS(I1,J1)                             QS007930
 162  CONTINUE                                                           QS007940
C     END                                                                QS007950
 2691 RELAXD= .FALSE.                                                    QS007960
 269  KK=KK+1                                                            QS007970
      IDEX=1                                                             QS007980
      ICOUNT=0                                                           QS007990
      KKK=KKK+1                                                          QS008000
      IF(KK.GT.NOWREL) OVEREL=RELSAV                                     QS008010
      IF(KK.GT.NOTYET) SUPREL=SUPSAV                                     QS008020
      IF(NOZ-1.NE.NOZIN)                                                 QS008030
     1UNDERL=UNDSAV+FLOAT(KKK)/FLOAT(NOTYET)*(OVEREL-UNDSAV)             QS008040
 272  I=I+1                                                              QS008050
      IM1= I-1                                                           QS008060
      IF(IM1.EQ.0) IM1=2                                                 QS008070
                                                                         QS008080
                                                                         QS008090
C      DO (AXIAL LOCATION INDICATORS)                                    QS008100
                                                                         QS008110
                                                                         QS008120
C      PROCEDURE  (AXIAL LOCATION INDICATORS)                            QS008130
                                                                         QS008140
      INLET=.FALSE.                                                      QS008150
      EXIT  = .FALSE.                                                    QS008160
```

```
      IF(I.EQ.1) INLET =.TRUE.                                          QS008170
      IF( I.EQ. IEXIT) EXIT=.TRUE.                                      QS008180
C     END                                                               QS008190
275   J=J+1                                                             QS008200
      JM1=J-1                                                           QS008210
      IF(JM1.FQ.0) JM1=2                                                QS008220
                                                                        QS008230
                                                                        QS008240
C     DO (VERTICAL LOCATION INDICATORS)                                 QS008250
                                                                        QS008260
                                                                        QS008270
C     PROCEDURE (VERTICAL LOCATION INDICATORS)                          QS008280
                                                                        QS008290
      BOTTOM = .FALSE.                                                  QS008300
      TOP    = .FALSE.                                                  QS008310
      BLADE  = .FALSE.                                                  QS008320
      IF(J.EQ.1) BOTTOM =.TRUE.                                         QS008330
      IF(J.EQ.M) TOP =.TRUE.                                            QS008340
      BLADE = TOP                                                       QS008350
C     END                                                               QS008360
                                                                        QS008370
                                                                        QS008380
C     DO (BOUNDARY CONDITION SWITCHES)                                  QS008390
                                                                        QS008400
                                                                        QS008410
C      PROCEDURE (BOUNDARY CONDITION SWITCHES)                          QS008420
                                                                        QS008430
      DO 209 I1=1,8                                                     QS008440
209   ONOFF(I1)=1.                                                      QS008450
C     IF(INLET) THEN                                                    QS008460
C     ONOFF(3)= 0.                                                      QS008470
C     ONOFF(4)= 0.                                                      QS008480
C     ONOFF(5)= 0.                                                      QS008490
C     ONOFF(6)= 0.                                                      QS008500
C     END                                                               QS008510
C     IF(BOTTOM) THEN                                                   QS008520
C     ONOFF(5)= 0.                                                      QS008530
C     ONOFF(6)= 0                                                       QS008540
C     ONOFF(7)= 0.                                                      QS008550
C     ONOFF(8)= 0.                                                      QS008560
C     END                                                               QS008570
C     IF(TOP) THEN                                                      QS008580
C     ONOFF(1)= 0.                                                      QS008590
C     ONOFF(2)= 0.                                                      QS008600
C     ONOFF(3)= 0.                                                      QS008610
C     ONOFF(4)= 0.                                                      QS008620
C     END                                                               QS008630
      IF(.NOT.INLET.AND..NOT.BOTTOM.AND..NOT.TOP ) GOTO235              QS008640
```

```
      IF(TOP)IS=1
      IF(INLET)IS=3
      IF(BOTTOM)IS=5
      IE=IS+3
      DO 2099 I1=IS,IE
2099  ONOFF(I1)=0.
C     END



C     DO (GEOMETRY ADVANCE)


C     PROCEDURE (GEOMETRY ADVANCE)

235   HITE(1)=XDIF(HEIGHT(I,J),HEIGHT(I+1,J),0.,0.)
      IF(I.EQ.IEXIT)HITE(1)=HEIGHT(I,J)
      HITE(2)=XDIF(HEIGHT(I,J),HEIGHT(I,J+1),0.,0.)
      HITE(3)=HITE(2)
      HITE(8)=HITE(1)
      SPAN(1)=XDIF(RADIUS(I,J),RADIUS(I+1,J),0.,0.)
      IF(I.EQ.IEXIT)SPAN(1)=RADIUS(I,J)
      SPAN(1)=SPAN(1)/FIXR
      SPAN(2)=XDIF(RADIUS(I,J),RADIUS(I,J+1),0.,0.)
      SPAN(2)=SPAN(2)/FIXR
      SPAN(3)=SPAN(2)
      SPAN(8)=SPAN(1)
      T(6) = -T(3)*ONOFF(6)
      T(7) = -T(2)*ONOFF(7)

C     CALCULATE THE METRICS ON THE FIRST ITERATION
C     STORE THEM FOR SUBSEQUENT ITERATIONS

      IF(KK.GT.2)GOTO237

C     CALCULATE VELOCITIES AT UP AND DOWNSTREAM BOUNDARY ELEMENTS TO SAT
C     MASS FLOW
C         INDEX(I,J)>0 POINTS TO BOUNDARY ELEMENTS AFFECTED

      IF(INDEX(I,J).EQ.0.OR.KK.GT.1)GOTO2037
      ICOUNT=ICOUNT+1
      I1S=I1DEX(ICOUNT)
      IDIF=INDEX(I,J)+I1S-1
      DO 9999 I11=I1S,IDIF
      I1=I11
      IF(I1S.EQ.1.AND.I1.EQ.IDIF)I1=8
      ROTATX=ROTATN*SPAN(I1)*FIXR/RADLE
      BIGKH=BIGK/HITE(I1)/SPAN(I1)
```

```
      U0=U0OUT
      DPHDTH=DPHTHO
      IF(ICOUNT.GE.11.AND.ICOUNT.LE.24)U0=U0IN
      IF(ICOUNT.GE.11.AND.ICOUNT.LE.24)DPHDTH=DPHTHI
      FAKEV(IDEX)=DPHDTH/SPAN(I1)
      VREL2=(FAKEV(IDEX)-ROTATX)**2
      ROTATX=ROTATX*ROTATX-ROTATN*ROTATN
      SETTLE=.FALSE.
      YEW=U0
      IF(NOTYET.GT.KKMAX)YEW=BIGKH
      JCOUNT=0
 1999 QSQAR=YEW*YEW+VREL2
      IF(QSQAR.GE.QLIM)QSQAR=.99*QLIM
      RHOFAC=RHOCON*(1.-QSQAR)+1.
      RHOFAC=RHOFAC+ROTATX*RHOCON
      IF(RHOFAC.LT.0..OR.NOTYET.GT.KKMAX)RHOFAC=1.
      EFF=YEW-BIGKH*RHOFAC**(-EXPO)
      DFDU=1.-MINF*MINF*YEW*BIGKH*RHOFAC**(-GAMMA*EXPO)
      DU=-EFF/DFDU
      SETTLE=ABS(DU)/YEW.LT..001.OR.JCOUNT.GT.20
      YEW =YEW +DU
      JCOUNT=JCOUNT+1
      IF(.NOT.SETTLE) GOTO1999
      IF(JCOUNT.GT.20)YEW=BIGKH
      IF(JCOUNT.GT.20)WRITE(6,1677) I,J,I1
 1677 FORMAT('OCALCULATION OF VELOCITY AT BOUNDARY ELEMENT I= ',I3,
     1' J= ','I1= ',I3,' EXCEEDS 20 ITERATIONS. PROCEEDING WITH'/
     1 'INCOMPRESSIBLE ASSUMPTION (VELOCITY.EQ.MASS FLOW/AREA) ' )
      FAKEU(IDEX)=YEW
 9999 IDEX=IDEX+1
      ICOUNT=ICOUNT-1
      IDEX=IDEX-INDEX(I,J)



C     IF(KK.LE.2) THEN
 2037 IF(TOP) GOTO239
C     IF(.NOT.TOP) THEN
      XABMXA = XDIF(X(I+1,J+1),X(I,J+1),X(I,J),X(I+1,J))*.5
      XABMXB =.5*XDIF(X(I+1,J+1),X(I+1,J),X(I,J),X(I,J+1))
      YABMYA =.5*XDIF(Y(I+1,J+1),Y(I,J+1),Y(I,J),Y(I+1,J))
      YABMYB =.5*XDIF(Y(I+1,J+1),Y(I+1,J),Y(I,J),Y(I,J+1))
      XBCMXB =.5*XDIF(X(IM1,J+1),X(IM1,J),X(I,J),X(I,J+1))
      YBCMYB =.5*XDIF(Y(IM1,J+1),Y(IM1,J),Y(I,J),Y(I,J+1))
      LAB    = SQRT( XABMXA*XABMXA + SPAN(1)*YABMYA*SPAN(1)*YABMYA)
      HAB    = SQRT( XABMXB*XABMXB + SPAN(2)*YABMYB*SPAN(2)*YABMYB)
      HBC    = SQRT( XBCMXB*XBCMXB + SPAN(3)*YBCMYB*SPAN(3)*YBCMYB)
      COSX(1)=  YABMYA*SPAN(1)/LAB
```

```
      COSX(2)=     -YABMYB*SPAN(2)/HAB
      COSX(3)=     YBCMYB*SPAN(3)/HBC
      COSY(1)=              -XABMXA/LAB
      COSY(2)=  XABMXB/HAB
      COSY(3)= -XBCMXB/HBC
C     END
239   IF(BOTTOM)GOTO241
C     IF(.NOT.BOTTOM) THEN
      XADMXA =.5*XDIF(X(I+1,JM1),X(I,JM1),X(I,J),X(I+1,J))
      YADMYA =.5*XDIF(Y(I+1,JM1),Y(I,JM1),Y(I,J),Y(I+1,J))
      LAD    = SQRT(XADMXA*XADMXA + SPAN(8)*YADMYA*SPAN(8)*YADMYA)
      COSX(8)= -YADMYA*SPAN(8)/LAD
      COSY(8)=  XADMXA/LAD
C     END
241   LENGTH(1) =  LAB
      LENGTH(2) =  HAB
      LENGTH(3) =  HBC
      LENGTH(8) =  LAD
      EXDIF1=X(I+1,J)-X(I,J)
      EXDIF2=X(IM1,J)-X(I,J)
      YDIF1=SPAN(1)*(Y(I+1,J)-Y(I,J))
      YDIF2=Y(IM1,J)-Y(I,J)
      SLEN=EXDIF1*EXDIF1+YDIF1*YDIF1
      ZETDF1    = ZETA(J+1) - ZETA(J)
      ZETDF2    = ZETA(JM1) - ZETA(J)
      ETADF1    = ETA(I+1)  - ETA(I)
      ETADF2 = ETA(IM1)-ETA(I)
C     CELL I, POINT  A
      EK4 = 2.*YABMYA/ZETDF1
      EK3 = (Y(I+1,J)-Y(I,J))/ETADF1
      EK2 = 2.*XABMXA/ZETDF1
      EK1 = (X(I+1,J)-X(I,J))/ETADF1
      L = 1
C     DO (TRANSFORMATION MATRIX)
C     PROCEDURE (TRANSFORMATION MATRIX)
      JACOB=EK1*EK4-EK2*EK3
      IF(JACOB.EQ.0.) GOTO243
C     IF(JACOB.NE.0.) THEN
      DEDX(L)= EK4/JACOB
      DEDY(L)=-EK2/JACOB/SPAN(1)
      DZDX(L)= -EK3/JACOB
      DZDY(L)=  EK1/JACOB/SPAN(1)
C     END
C     END
243   EK4 = 2.*YADMYA/ZETDF2
C           CELL  IV,  POINT A
      EK2 = 2.*XADMXA/ZETDF2
      L=8
```

```
C     DO (TRANSFORMATION MATRIX)
      JACOB=EK1*EK4-EK2*EK3
      IF(JACOB.EQ.0.)GOTO245
C     IF(JACOB.NE.0.) THEN
      DEDX(L)= EK4/JACOB
      DEDY(L)=-EK2/JACOB/SPAN(8)
      DZDX(L)= -EK3/JACOB
      DZDY(L)=  EK1/JACOB/SPAN(8)
C     END
C     CELL II, POINT B
245   EK4  = (Y(I,J+1)-Y(I,J))/ZETDF1
      EK3  = 2.*YBCMYB/ETADF2
      EK2  = (X(I,J+1)-X(I,J))/ZETDF1
      EK1  = 2.*XBCMXB/ETADF2
      L=3
C     DO (TRANSFORMATION MATRIX)
      JACOB=EK1*EK4-EK2*EK3
      IF(JACOB.EQ.0.)GOTO247
C     IF(JACOB.NE.0.) THEN
      DEDX(L)= EK4/JACOB
      DEDY(L)=-EK2/JACOB/SPAN(3)
      DZDX(L)= -EK3/JACOB
      DZDY(L)=  EK1/JACOB/SPAN(3)
C     END
C     CELL I, POINT B
247   EK1 = 2.*XABMXB/ETADF1
      EK3 = 2.*YABMYB/ETADF1
      L=2
C     DO (TRANSFORMATION MATRIX)
      JACOB=EK1*EK4-EK2*EK3
      IF(JACOB.EQ.0.)GOTO249
C     IF(JACOB.NE.0.) THEN
      DEDX(L)= EK4/JACOB
      DEDY(L)=-EK2/JACOB/SPAN(2)
      DZDX(L)= -EK3/JACOB
      DZDY(L)=  EK1/JACOB/SPAN(2)
C     END
249   T(1)=LENGTH(1)*HITE(1)*(DEDX(1)*COSX(1)+DEDY(1)*COSY(1
     1))*ONOFF(1)
      T(2)=LENGTH(2)*HITE(2)*(DZDX(2)*COSX(2)+DZDY(2)*COSY(2
     1))*ONOFF(2)
      T(3)=LENGTH(3)*HITE(3)*(DZDX(3)*COSX(3)+DZDY(3)*COSY(3
     1))*ONOFF(3)
      T(8)=LENGTH(8)*HITE(8)*(DEDX(8)*COSX(8)+DEDY(8)*COSY(8
     1))*ONOFF(8)

C     STORE METRICS AND GEOMETRY AT POINT I,J
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```
      SUPERG(1,J,I)=COSX(1)
      SUPERG(2,J,I)=COSX(2)
      SUPERG(3,J,I)=COSX(3)
      SUPERG(4,J,I)=COSX(8)
      SUPERG(5,J,I)=COSY(1)
      SUPERG(6,J,I)=COSY(2)
      SUPERG(7,J,I)=COSY(3)
      SUPERG(8,J,I)=COSY(8)
      SUPERG(9,J,I)=LENGTH(1)
      SUPERG(10,J,I)=LENGTH(2)
      SUPERG(11,J,I)=LENGTH(3)
      SUPERG(12,J,I)=LENGTH(8)
      SUPERG(13,J,I)=EXDIF1
      SUPERG(14,J,I)=EXDIF2
      SUPERG(15,J,I)=YDIF1
      SUPERG(16,J,I)=YDIF2
      SUPERG(17,J,I)=SLEN
      SUPERG(18,J,I)=SLEN2
      SUPERG(19,J,I)=ZETDF1
      SUPERG(20,J,I)=ZETDF2
      SUPERG(21,J,I)=ETADF1
      SUPERG(22,J,I)=ETADF2
      SUPERG(23,J,I)=DEDX(1)
      SUPERG(24,J,I)=DEDX(2)
      SUPERG(25,J,I)=DEDX(3)
      SUPERG(26,J,I)=DEDX(8)
      SUPERG(27,J,I)=DEDY(1)
      SUPERG(28,J,I)=DEDY(2)
      SUPERG(29,J,I)=DEDY(3)
      SUPERG(30,J,I)=DEDY(8)
      SUPERG(31,J,I)=DZDX(1)
      SUPERG(32,J,I)=DZDX(2)
      SUPERG(33,J,I)=DZDX(3)
      SUPERG(34,J,I)=DZDX(8)
      SUPERG(35,J,I)=DZDY(1)
      SUPERG(36,J,I)=DZDY(2)
      SUPERG(37,J,I)=DZDY(3)
      SUPERG(38,J,I)=DZDY(8)
      SUPERG(39,J,I)=T(1)
      SUPERG(40,J,I)=T(2)
      SUPERG(41,J,I)=T(3)
      SUPERG(42,J,I)=T(8)
C       SINCE( KK.LE.2)
      GOTO 238
C
C     ELSE
C    IF ITERATION COUNT EXCEEDS 2, OBTAIN METRICS, ETC. FROM STORAGE
```

```
237   COSX(1)=SUPERG(1,J,I)
      COSX(2)=SUPERG(2,J,I)
      COSX(3)=SUPERG(3,J,I)
      COSX(8)=SUPERG(4,J,I)
      COSY(1)=SUPERG(5,J,I)
      COSY(2)=SUPERG(6,J,I)
      COSY(3)=SUPERG(7,J,I)
      COSY(8)=SUPERG(8,J,I)
      LENGTH(1)=SUPERG(9,J,I)
      LENGTH(2)=SUPERG(10,J,I)
      LENGTH(3)=SUPERG(11,J,I)
      LENGTH(8)=SUPERG(12,J,I)
      EXDIF1=SUPERG(13,J,I)
      EXDIF2=SUPERG(14,J,I)
      YDIF1=SUPERG(15,J,I)
      YDIF2=SUPERG(16,J,I)
      SLEN=SUPERG(17,J,I)
      SLEN2=SUPERG(18,J,I)
      ZETDF1=SUPERG(19,J,I)
      ZETDF2=SUPERG(20,J,I)
      ETADF1=SUPERG(21,J,I)
      ETADF2=SUPERG(22,J,I)
      DEDX(1)=SUPERG(23,J,I)
      DEDX(2)=SUPERG(24,J,I)
      DEDX(3)=SUPERG(25,J,I)
      DEDX(8)=SUPERG(26,J,I)
      DEDY(1)=SUPERG(27,J,I)
      DEDY(2)=SUPERG(28,J,I)
      DEDY(3)=SUPERG(29,J,I)
      DEDY(8)=SUPERG(30,J,I)
      DZDX(1)=SUPERG(31,J,I)
      DZDX(2)=SUPERG(32,J,I)
      DZDX(3)=SUPERG(33,J,I)
      DZDX(8)=SUPERG(34,J,I)
      DZDY(1)=SUPERG(35,J,I)
      DZDY(2)=SUPERG(36,J,I)
      DZDY(3)=SUPERG(37,J,I)
      DZDY(8)=SUPERG(38,J,I)
      T(1)=SUPERG(39,J,I)
      T(2)=SUPERG(40,J,I)
      T(3)=SUPERG(41,J,I)
      T(8)=SUPERG(42,J,I)
C     END
C     CELL  II,  POINT  C
238   T(5) =  PRIORS(1,J)*ONOFF(5)
      T(4) =  PRIORS(2,J)*ONOFF(4)
      PRIORS(1,J) = - T(8)
```

```
      PRIORS(2,J) = - T(1)
C     END


C     DO (FIELD GRADIENTS)

C     PROCEDURE (FIELD GRADIENTS)

      DO 438 I1=1,3
      FI1(I1)=PHI(I+1,J)
      FI2(I1)=PHI(I+1,J+1)
      FI3(I1)=PHI(I  ,J+1)
  438 FI9(I1)=PHI(I  ,J  )
      FI4    =PHI(IM1,J+1)
      FI5    =PHI(IM1,J  )
      FI6    =PHI(IM1,JM1)
      FI7    =PHI(I  ,JM1)
      FI8    =PHI(I+1,JM1)
      FI1(8)=PHI(I+1,J)
      FI9(8)=PHI(I  ,J)
      I10=I-IEXIT+3
C     CELL I , POINT A
  251 DPHIDZ(1)= XDIF(FI3(1),FI2(1),FI9(1),FI1(1))/ZETDF1
      DPHIDE(1) =  (FI1(1)-FI9(1))/ETADF1
C     CELL I, POINT B
      DPHIDE(2)=XDIF(FI1(2),FI2(2),FI9(2),FI3(2)) /ETADF1
      DPHIDZ(2)=(FI3(2)-FI9(2))/ZETDF1
C     CELL II, POINT B
      DPHIDE(3)=XDIF(FI5,FI4,FI9(3),FI3(3)) /ETADF2
      DPHIDZ(3)=(FI3(3)-FI9(3))/ZETDF1
C     CELL IV, POINT A
      DPHIDE(8) =  (FI1(8)-FI9(8))/ETADF1
      DPHIDZ(8) =XDIF(FI7,FI8,FI9(8),FI1(8))/ZETDF2
C     END


C     DO (VELOCITIES AND DENSITIES)

C     PROCEDURE (VELOCITIES AND DENSITIES)

      U(6) = U(3)
      V(6) = V(3)
      U(7) = U(2)
```

```
      V(7) = V(2)                                                       QS012010
      DO 541 I1 =1,8                                                    QS012020
      IF(I1.GE.4.AND.I1.NE.8) GOTO 541                                  QS012030
C     IF(I1.LT.4.OR.I1.EQ.8) THEN                                       QS012040
      U(I1)=DPHIDE(I1)*DEDX(I1)+ DPHIDZ(I1)*DZDX(I1)                    QS012050
      V(I1)=DPHIDE(I1)*DEDY(I1)+ DPHIDZ(I1)*DZDY(I1)                    QS012060
      IF(INDEX(I,J).EQ.0)GOTO5411                                       QS012070
      ICOUNT=ICOUNT+1                                                   QS012080
      I1S=I1DEX(ICOUNT)                                                 QS012090
      IF(I1.LE.I1S)I1P=I1S                                              QS012100
      IDIF=INDEX(I,J)+I1S-1                                             QS012110
      IF(I1S.EQ.1.AND.I1P.EQ.IDIF)I1P=8                                 QS012120
      IF(I1.NE.I1P)GOTO5410                                             QS012130
      IF(I1P.GT.IDIF.AND.I1P.NE.8)GOTO5410                              QS012140
      V(I1)=FAKEV(IDEX)                                                 QS012150
      U(I1)=FAKEU(IDEX)                                                 QS012160
      IDEX=IDEX+1                                                       QS012170
      I1P=I1P+1                                                         QS012180
5410  IF(I1.NE.8)ICOUNT=ICOUNT-1                                        QS012190
5411  V(I1)=V(I1)-SPAN(I1)*FIXR/RADLE*ROTATN                            QS012200
      UN(I1)=U(I1)*COSX(I1)+V(I1)*COSY(I1)                              QS012210
C     END                                                               QS012220
541   CONTINUE                                                          QS012230
      IF(.NOT.TOP) GOTO 2003                                            QS012240
      U8=SQRT(U(8)*U(8)+V(8)*V(8))*ABS(EXDIF1)/SQRT(SLEN)               QS012250
      IF(KK.GT.7.OR.ABS(FLOCO).GT..01)U(8)=SIGN(U8,U(8))                QS012260
      V(8)=U(8)*YDIF1/EXDIF1                                            QS012270
      UN(8)=U(8)*COSX(8)+V(8)*COSY(8)                                   QS012280
C     END                                                               QS012290
2003  U(4) =  PRIORS(3,J)                                               QS012300
      U(5) =  PRIORS(4,J)                                               QS012310
      V(4) =  PRIORS(5,J)                                               QS012320
      V(5) =  PRIORS(6,J)                                               QS012330
      PRIORS(3,J)=U(1)                                                  QS012340
      PRIORS(4,J)=U(8)                                                  QS012350
      PRIORS(5,J)=V(1)                                                  QS012360
      PRIORS(6,J)=V(8)                                                  QS012370
      RHO(7)=RHO(2)                                                     QS012380
      RHO(6)=RHO(3)                                                     QS012390
      RHO(4)=PRIORS(7,J)                                                QS012400
      RHO(5)=PRIORS(8,J)                                                QS012410
      ONSUM=0.                                                          QS012420
      DO 595 I1=1,8                                                     QS012430
                                                                        QS012440
C     IF(KK.LE.2.OR.MOD(KK,2).EQ.0) THEN                                QS012450
      IF(I1.GE.4.AND.I1.NE.8) GOTO 2005                                 QS012460
C     IF(I1.LT.4.OR.I1.EQ.8) THEN                                       QS012470
      RHOFAC=1.                                                         QS012480
```

```
      RHO(I1)=1.
      IF((I.EQ.2.OR.I.EQ.IEXIT).AND.J.LE.4.AND.ROTATN.NE.0.
     1.OR.KK.LE.NOTYET) GOTO 2005
      QSQAR=U(I1)*U(I1)+(V(I1)*V(I1))
      IF(QSQAR.GE.QLIM)QSQAR=.99*QLIM
      RHOFAC=RHOCON*(1.-QSQAR)*ONOFF(I1)+1.
      RHO(I1)=1.-AMZ*(QSQAR-1.)+AMY*(QSQAR-1.)*(QSQAR-1.)
      IF(QSQAR.LT..65.OR.QSQAR.GT.1.44)RHO(I1)=RHOFAC**EXPO

C CORRECT DENSITY FOR ROTATION

      ROTATX=SPAN(I1)*FIXR/RADLE
      IF(ROTROT.NE.0..AND.J.GT.3)
     1RHO(I1)=(RHO(I1)**(1./EXPO)+RHOCON*ROTROT*((ROTATX)
     1**2-1.)*ONOFF(I1))**EXPO
2005  QSQAR=U(I1)*U(I1)+V(I1)*V(I1)
      IF(I.GT.1)
     1MACH(I1)=MINF*SQRT(QSQAR)/RHO(I1)**(1./EXPO)
C    1MACH(I1)=MINF*SQRT(QSQAR/RHO(I1)**(1./EXPO))
      IF(MACH(I1).GT.2.)MACH(I1)=2.
595   CONTINUE
      PRIORS(7,J)=RHO(1)
      PRIORS(8,J)=RHO(8)
C     END


C     DO (SUPERSONIC CORRECTION)


C     PROCEDURE (SUPERSONIC CORRECTION)

      ONSUM=0.
      ROSUM=RHO(4)+RHO(5)+RHO(6)+RHO(7)
      EMACH(I,J)=0.
      XVELIJ=0.
      DO 608 I3=1,8
      RHOSS(I3)=0.
608   ONSUM=ONSUM+ONOFF(I3)
      YVELIJ=0.
      SMALLA=0.
      SMALLB=0.
      ZETDF1=ZETA(J+1)-ZETA(J)
      IF(J.EQ.M)ZETDF1=ZETA(J)-ZETA(J-1)
      EMACH(I,J)=(ONOFF(1)*MACH(1)+ONOFF(8)*MACH(8))/(ONOFF(1)+ONOFF(8)
     1)
      EMACH(IEXIT+1,J)=EMACH(3,J)
      EMACH(1,J)=EMACH(IEXIT-1,J)
```

```
C     IF(KK.LE.2.OR.MOD(KK,IT).EQ.0.OR.MOD(KK,IT).GE.IT/2) THEN
C       STORE DENSITIES FROM SURFACE OF ELEMENT IN DUMMY ARRAYS

      DUMBX(I,J)=(ONOFF(1)*RHO(1)+ONOFF(8)*RHO(8))/(ONOFF(1)+ONOFF(8)
     1)
      IF(.NOT.TOP)DUMBY(I,J)=(ONOFF(2)*RHO(2)+ONOFF(3)*RHO(3))/
     1(ONOFF(2)+ONOFF(3))
      IF(.NOT.TOP)ZMACH(I,J)=(ONOFF(2)*MACH(2)+ONOFF(3)*MACH(3))/
     1(ONOFF(2)+ONOFF(3))
      IF(TOP)DUMBY(I,J)=2.*DUMBY(I,J-1)-DUMBY(I,J-2)
      IF(TOP)ZMACH(I,J)=2.*ZMACH(I,J-1)-ZMACH(I,J-2)
      DUMBX(IEXIT+1,J)=DUMBX(3,J)
      ZMACH(1,J)=ZMACH(IEXIT-1,J)
      DUMBY(I,M+1)=2.*DUMBY(I,1)-DUMBY(I,2)
      ZMACH(I,M+1)=2.*ZMACH(I,1)-ZMACH(I,2)

C     CALCULATE DENSITY CORRECTION TERMS,  MU*DRHODS*DS

C     IF(J.GT.5.OR.I.LT.NOZ-1.OR.I.GT.NOZ+1) THEN
      IF(J.LE.5.AND.I.GE.NOZ-1.AND.I.LE.NOZ+1) GOTO20001
      DO 694 I1=2,8,6
      IF(TOP.AND.I1.NE.8) GOTO 694
C     IF(.NOT.TOP.OR.I1.EQ.8) THEN
      I1P1=I1+1
      IF(I1.EQ.8)I1P1=1
      ONSUM=ONOFF(I1)+ONOFF(I1P1)
      XVELIJ=U(I1)*ONOFF(I1)/ONSUM
      XVELIJ=XVELIJ+U(I1P1)*ONOFF(I1P1)/ONSUM
      YVELIJ=V(I1)*ONOFF(I1)/ONSUM
      YVELIJ=YVELIJ+V(I1P1)*ONOFF(I1P1)/ONSUM
      SMALLA=(U(I1)*DZDX(I1)+V(I1)*DZDY(I1))*ONOFF(I1)/ONSUM
      SMALLA=SMALLA+(U(I1P1)*DZDX(I1P1)+V(I1P1)*DZDY(I1P1))
     1*ONOFF(I1P1)/ONSUM
      SMALLB=(U(I1)*DEDX(I1)+V(I1)*DEDY(I1))*ONOFF(I1)
     1/ONSUM
      SMALLB=SMALLB+(U(I1P1)*DEDX(I1P1)+V(I1P1)*DEDY(I1P1))
     1*ONOFF(I1P1)/ONSUM
      IF(KK.LE.NOTYET) GOTO694
C     IF(KK.GT.NOTYET) THEN
      IF(BLADE)SMALLA=0.
      SIGNOA=SIGN(1.,SMALLA)
      IF(SMALLA.EQ.0.)SIGNOA=1.
      FLOWAT=AMAX1(0.,SIGNOA)
      SIGNOB=SIGN(1.,SMALLB)
      FLOWBY=AMAX1(0.,SIGNOB)
      QUE=SQRT(XVELIJ**2+YVELIJ**2)
C        SLP2=TEGARD
      IF(ABS(SMALLB)/QUE.GT.SLP2)QUE=SQRT(SMALLA**2+SMALLB**2)
```

```
      MYJ=J-IFIX(SIGNOA)
      MYI=I-IFIX(SIGNOB)
      JYM=MYJ+IFIX(FLOWAT)
      IYM=MYI+IFIX(FLOWBY)
      IF(MYJ.EQ.0)MYJ=2
      IF(MYI.EQ.0)MYI=IEXIT-2
      IYM1=IYM-1
      IF(IYM1.EQ.0)IYM1=1
      JYM1=JYM-1
      IF(JYM1.EQ.0)JYM1=1
      IF(I1.EQ.2) GOTO2019
C     IF(I1.EQ.8) THEN
      MACHA=(EMACH(I,J)+EMACH(I,MYJ))/2.
      MACHB=(EMACH(I,J)+EMACH(MYI,J))/2.
      SWICHA=-AMAX1(0.,1./SHIFTM**2-1./MACHA/MACHA)/QUE
      SWICHB=-AMAX1(0.,1./SHIFTM**2-1./MACHB/MACHB)/QUE

C    RHOSS(2)=MU*DRHODS*DS AT TOP OF ELEMENT
C    RHOSS(8)=MU*DRHODS*DS ON FORWARD, SWEEPING EDGE OF ELEMENT
      RHOSS(I1)=SWICHB*SIGNOB*SMALLB*(DUMBX(I,J)-DUMBX(MYI,J))+
     1          SWICHA*SIGNOA*SMALLA*(DUMBX(I,J)-DUMBX(I,MYJ))
C     SINCE (I1.NE.2)
      GOTO 2020
2019  MACHA=(ZMACH(I,J)+ZMACH(I,MYJ))/2.
      MACHB=(ZMACH(I,J)+ZMACH(MYI,J))/2.
      SWICHA=-AMAX1(0.,1./SHIFTM**2-1./MACHA/MACHA)/QUE
      SWICHB=-AMAX1(0.,1./SHIFTM**2-1./MACHB/MACHB)/QUE
      RHOSS(I1)=SWICHB*SIGNOB*SMALLB*(DUMBY(I,J)-DUMBY(MYI,J))+
     1          SWICHA*SIGNOA*SMALLA*(DUMBY(I,J)-DUMBY(I,MYJ))
C     END
2020  RHOSS(I1P1)=RHOSS(I1)
      RHO(I1)=RHO(I1)+DAMP*RHOSS(I1)*ONOFF(I1)
      IF(RHO(I1).LE.0.)RHO(I1)=RHO(I1)-2.*
     1DAMP*RHOSS(I1)*ONOFF(I1)
      RHO(I1P1)=RHO(I1P1)+DAMP*RHOSS(I1P1)*ONOFF(I1P1)
      IF(RHO(I1P1).LE.0.)RHO(I1P1)=RHO(I1P1)-2.*
     1DAMP*RHOSS(I1P1)*ONOFF(I1P1)
      PRIORS(7,J)=RHO(1)
      PRIORS(8,J)=RHO(8)
3334  FORMAT(2I8,7E13.5)
C     END
C     END
694   CONTINUE
C     END
20001 CONTINUE
C     END
C     END
```

```
C     DO ( T'S,Q'S AND RESIDUALS)

C     PROCEDURE ( T'S,Q'S AND RESIDUALS)

C     NET MASS FLOW TERM
      ONSUM=0.
      FLONET = -RHOUL(2)*ONOFF(7)-RHOUL(3)*ONOFF(6)+PRIORS(9,J)*ONOFF(4
     1) + PRIORS(10,J)*ONOFF(5)
      DO 711 I1=1,8
      ONSUM=ONSUM+ONOFF(I1)
      IF(I1.GE.4.AND.I1.NE.8) GOTO 711
C     IF(I1  .LT.4.OR.I1.EQ.8) THEN
      ROSUM=ROSUM+RHO(I1)
      RHOUL(I1)= RHO(I1)*UN(I1)*LENGTH(I1)* HITE(I1)*ONOFF(I1)
      FLONET =FLONET + RHOUL(I1)
C     END
711   CONTINUE
      ROAVG=ROSUM/ONSUM
      TENOLF(I,J)=FLONET
      PRIORS(9,J) = -RHOUL(1)
      PRIORS(10,J) = -RHOUL(8)
C
C     RESIDUAL TOTAL
      R=-FLONET
C     END
C     IF(BUG) DO (FIRST DEBUG LIST)


C     PROCEDURE (FIRST DEBUG LIST)

C      BUG AND BUG3 ARE NOT INCLUDED IN NAMELIST PARAMS. THEY MUST BE
C        ADDED OR SET HERE MANUALLY IN ORDER TO ACTIVATE THESE PRINTOUTS.

      IF(.NOT.EXIT.OR.MOD(KK,IT).NE.0.OR..NOT.TOP.OR..NOT.BUG) GOTO 2023
C     IF(EXIT.AND.MOD(KK,IT).EQ.0.AND.TOP.AND.BUG) THEN
      WRITE(6,YTESD)
      IF(.NOT.BUG3) GOTO2025
C     IF(BUG3) THEN
      WRITE(6,7001)
7001  FORMAT('0ARRAY OF POTENTIAL CORRECTIONS,BLADE SURFACE=FAR RIGHT',
     1' COLUMN')
      DO 732 I2=1,IEXIT
732   WRITE(6,9)(DELPSV(I2,J2),J2=I67,M)
      WRITE(6,7002)
7002  FORMAT('0ARRAY OF POTENTIAL VALUES,BLADE SURFACE=FAR RIGHT ',
```

```
     1'COLUMN')
      DO 738 I2=1,IEXIT
738   WRITE(6,9)(PHI(I2,J2),J2=I67,M)
C     END
2025  WRITE(6,7003)
7003  FORMAT('OARRAY OF RESIDUAL MASS FLOWS,BLADE SURFACE=FAR RIGHT',
     1' COLUMN')
      DO 745 I2=1,IEXIT
745   WRITE(6,9)(TENOLF(I2,J2),J2=I67,M)
      WRITE(6,7004)
7004  FORMAT('OARRAY OF MACH NUMBERS,BLADE SURFACE=FAR RIGHT COLUMN')
      DO 750 I2=1,IEXIT
750   WRITE(6,9)(EMACH(I2,J2),J2=I67,M)
      REWIND 8
      WRITE(8,2) PHI
C     END
9     FORMAT(1H ,14E9.3)
C     END



C     DO ( DELPHI COEFFICIENTS AND TRANSPOSED TERMS)

C     PROCEDURE ( DELPHI COEFFICIENTS AND TRANSPOSED TERMS)
C
C     AIJP1*DELPHI(I,J+1)+AIJ*DELPHI(I,J)+AIJM1*DELPHI(I,J-1)= R + BIGZ

C
2023  DELPM1(2) = DELPHI(J)
      IF(I.EQ.2)DELPM1(2)=DELPSV(IEXIT-1,J)
      IF(KK.GT.2.AND.MOD(KK,IT).NE.0) GOTO 2029
C     IF(KK.LE.2.OR.MOD(KK,IT).EQ.0) THEN
      AIJP1=(T(2)*RHO(2)+T(3)*RHO(3))/ZETDF1
      AIJM1=(T(6)*RHO(6)+T(7)*RHO(7))/ZETDF2
      TT18=(T(1)*RHO(1)+T(8)*RHO(8))/ETADF1
      ZIM1J=(T(4)*RHO(4)+T(5)*RHO(5))/ETADF2
      AIJ=-1.*(AIJM1+AIJP1+TT18+ZIM1J)
      ZIP1J=0.
      ZJP1=0.
      ZJM1=0.

C   SAVE COEFFICIENTS UNTIL THE NEXT TIME DENSITY IS UPDATED (WHEN KK IS
C   DIVISIBLE BY IT).
      SUPERG(43,J,I)=AIJ
      SUPERG(44,J,I)=AIJM1
      SUPERG(45,J,I)=AIJP1
      SUPERG(46,J,I)=ZIM1J
      ZIM1J=ZIM1J*DELPM1(2)
```

```
C      SINCE (KK.LE.2.OR.MOD(KK,IT).EQ.0)
       GOTO 2030

C    IF ITERATION COUNT EXCEEDS 2 AND IS NOT DIVISIBLE BY IT, OBTAIN
C    COEFFICIENTS FROM THE LAST CALCULATION.
2029   AIJ=SUPERG(43,J,I)
       AIJM1=SUPERG(44,J,I)
       AIJP1=SUPERG(45,J,I)
       ZIM1J=SUPERG(46,J,I)
       ZIM1J=ZIM1J*DELPM1(2)
       ZJP1=0.
       ZJM1=0.
C      END
2030   BIGZ = -(ZIP1J +ZIM1J + ZJP1 + ZJM1)
       IF(J.EQ.4)BIGZ=BIGZ-AIJM1*DELPSV(IEXIT+2-I,5)
       TRANSP = R +BIGZ

C     ELIMINATE CHANGES TO PHI(BY ZEROING COEFFICIENTS)ON ALL DUMMY LINES
C     BEYOND  PERIODIC LINE.
       IF(.NOT.(J.LT.4.OR.(J.LE.5.AND.
      1(I.LE.3.OR.I.GE.IEXIT-1.OR.I.EQ.NOZ-1.OR.
      1I.EQ.NOZ.OR.I.EQ.NOZ+1)))) GOTO 2031
C      AIJ=0.
       AIJM1=0.
       AIJP1=0.
       TRANSP=0.

C      STORE COEFFICIENTS FOR LATER TRIDIAGONAL SOLUTION OF THIS LINE
2031   PRIORS(11,J)=AIJ
       PRIORS(12,J)=AIJP1
       PRIORS(13,J)=AIJM1
       PRIORS(14,J)=TRANSP


C    PROCEED TO NEXT VALUE OF J ON THIS RADIATING LINE
       IF(.NOT.TOP)GOTO275
C      END



C      DO (FORWARD ELIMINATION)


C      PROCEDURE (FORWARD ELIMINATION)

       DO 828 J=1,M
       JM1=J-1
       IF(JM1.EQ.0) JM1=2
```

```
      BOTTOM = .FALSE.
      TOP    = .FALSE.
      BLADE  = .FALSE.
      IF(J.EQ.1) BOTTOM =.TRUE.
      IF(J.EQ.M) TOP =.TRUE.
      BLADE = TOP

C    RECOVER COEFFICIENTS
      AIJ=PRIORS(11,J)
      AIJP1=PRIORS(12,J)
      AIJM1=PRIORS(13,J)
      TRANSP=PRIORS(14,J)
      IF(BOTTOM) GOTO 828
C     IF(.NOT.BOTTOM) THEN
      FFAC=AIJ-AIJM1*E(JM1)
      E(J)= +AIJP1/FFAC
      F(J)=  (TRANSP - AIJM1*F(JM1))/FFAC
3333  FORMAT(9E13.5)
C     END

828   CONTINUE
C     END


C     IF(I.NE.1)
C    1DO (BACK SUBSTITUTION)


C     PROCEDURE (BACK SUBSTITUTION)

      DELPHI(M)=F(M)
      OV=OVEREL
      IF(KKK.LT.NOTYET)OV=UNDERL
      IF(EMACH(I,M).GE.1.)OV=SUPREL*(1.-D(M)*(1.-CI))
      DELPSV(I,M)=DELPHI(M)*OV
      J=M-1
856   IF(J.LT.1)GOTO857
3335  FORMAT(3I6,9E12.5)
      BOTTOM = .FALSE.
      TOP    = .FALSE.
      BLADE  = .FALSE.
      IF(J.EQ.1) BOTTOM =.TRUE.
      IF(J.EQ.M) TOP =.TRUE.
      BLADE = TOP
      IF(.NOT.BOTTOM) DELPHI(J)=-E(J)*DELPHI(J+1)+F(J)
      OV=OVEREL
      IF(KKK.LT.NOTYET)OV=UNDERL
```

```
      IF(EMACH(I,J).GE.1.)OV=SUPREL*(1.-D(J)*(1.-CI))
      DELPSV(I,J)= DELPHI(J)*OV
      J=J-1
      GOTO856
857   CONTINUE
C     END
      J=0


C      GO TO NEXT RADIATING LINE

      IF(.NOT.EXIT)GOTO272
      TOT=0.





C     IF ALL LINES ARE COMPLETED, THEN
C     DO (UPDATE OF FIELD VARIABLES)


C     PROCEDURE (UPDATE OF FIELD VARIABLES)

      DO 871 I =2,IEXIT
      DO 871 J1=1,M
      PHI(I ,J1)= PHI(I ,J1)+DELPSV(I ,J1)
871   IF(J1.GE.4.AND.I.GT.1.AND.(ABS(DELPSV(I,J1)).LT.TEST*AVGFAC*GUESS
     1/FLOAT(IEXIT-1)/FLOAT(M-3).OR.KKK.LT.NOTYET))
     1TOT=TOT+ABS(DELPSV(I,J1))
      SSFAC=RADLE/FIXR*S*AQINF1*SIN(LAMDAO+BETA1)
      DO 880 I1=2,IEXIT
      IF(I1.EQ.NOZ) GOTO 880
C     IF(I1.NE.NOZ) THEN
      SFAC=SSFAC*FLOAT(ISIGN(1,I1-NOZ))

C      CORRECT THE DUMMY LINES BEYOND PERIODIC BOUNDARY USING PERIODICIT
C     Y
C      CONDITION.
      DO 878 J1=1,3
878   PHI(I1,J1)=PHI(IEXIT+2-I1,8-J1)+SFAC
C     END
880   CONTINUE

C       UPDATE DUMMY LINES ON EACH SIDE OF BRANCH CUT

      DO 890 J1=1,M
      PHI(1,J1)=
```

```
      1PHI(IEXIT-1,J1)-CIRCO
C     1PHI(IEXIT-1,J1)-RADLE/FIXR*S*(AQINF1*SIN(LAMDA0+BETA1)-AQINF2*SIN(
C     1LAMDA0+BETA2)/P1OP2)
890    PHI(IEXIT+1,J1)=PHI(3,J1)+
      1CIRCO
C     1      RADLE/FIXR*S*(AQINF1*SIN(LAMDA0+BETA1)-AQINF2*SIN(LAMDA0+
C     1BETA2)/P1OP2)
C      END



C      DO (CONVERGENCE TESTS)


C       PROCEDURE (CONVERGENCE TESTS)

       RELAXD=.FALSE.
       NOZO2=NOZ/2
       MO2=M/2
       AVGFAC=FLOAT(IEXIT-2)*FLOAT(M-3)*ABS(PHI(NOZO2,MO2))
       TEST=TOT/AVGFAC
       CIRCN=PHI(IEXIT,M)-PHI(2,M)
       DCIRC=(CIRCN-CIRCO)/CIRCOO
       IF(TOL.GT.0..AND.TOL.LT.1..AND.ABS(TEST).LT.TOL)RELAXD =.TRUE.
       IF(TOL.GT.1..AND.KK.GE.IFIX(TOL))RELAXD=.TRUE.
       TRUNC=ABS(TOL)
       IF(TOL.LT.0..AND.ABS(DCIRC).LT.TRUNC.AND.KKK.GT.50)RELAXD=.TRUE.
       IF(KKK.GE.KKMAX)RELAXD=.TRUE.
       TESMAC=0.
       DO 909 I=2,IEXIT
       RF=(.5*(DUMBX(I,M)+DUMBX(I-1,M)))**(1./2./EXPO)
       HIMAC=.5*(EMACH(I,M)+EMACH(I-1,M))*RF
       IF(HIMAC.GT.TESMAC.AND.ABS(X(I,M)/COS(LAMDA0))
      1.LT..44)TESMAC=HIMAC
909    CONTINUE
       IF(MOD(KK,IT).EQ.0.OR.BUG.OR.RELAXD)
      1WRITE(6,99) KK,TEST,TRANSP,TESMAC,CIRCN,DCIRC,OVEREL,SUPREL
99     FORMAT(1H ,4X,I4,4X,7E14.6)
C      END
       I=0



       IF(.NOT.RELAXD)GOTO269


C       OTHERWISE
C      DO (SURFACE FLOW CALCULATION FOR FINISHED GRID)
```

```
C       PROCEDURE (SURFACE FLOW CALCULATION FOR FINISHED GRID)

        WRITE(6,781) M3,ITIEX
        ICOUNT=0
        IDEX=1
        DO 937 I=1,IEXIT
        I1M=I-1
        IM1=I1M
        IF(IM1.EQ.0)IM1=2
        FIRSTJ=M-2
        LINEI=I

C       DO (VELOCITY CALCULATION ALONG RADIATING LINE)
        CALL SPEEDS(LINEI,FIRSTJ)

937     IF(I1M.GT.0)
       1WRITE(6,782)I1M,XOCX,FADBOP,X(I,M),Y(I,M),D(M),BOPR,
       1PHI(I,M),E(M),F(M),DELPHI(M)
781     FORMAT(1H0/1H0,22X,
       1'FINAL FLOW CALCULATION ON BLADE SURFACE FOR THE ',I3,
       1' BY ',I3,' MESH '//'  RADIATING',50X,'  STATIC  '/'  LINE NO. ',
       1'     X/CX       Y/CX        X            Y          MACH    PRES ',
       1'COEF     PHI       XVEL       YVEL       DENSITY '/)
782     FORMAT(I6,4X,10F10.5)
C       END

        RETURN

        ENTRY KEEPER

C       DO (OUTPUT OF PHI AND CALCULATION OF FINAL VELOCITY FIELD)

C       PROCEDURE (OUTPUT OF PHI AND CALCULATION OF FINAL VELOCITY FIELD)

        REWIND 7
10      FORMAT(5E15.8)

        ENT=1.
```

```
      EXI=1.
      IF(ALLOUT)WRITE(6,131) M3,ITIEX
131   FORMAT(1H1,38X,' CALCULATED FLOW FIELD AT ALL GRID POINTS '/1H0,
     138X,
     1'SURFACE CONTOUR NO.  1  = PERIODIC BOUNDARY'/40X,'SURFACE CONT',
     1'OUR NO. ',
     1I3,' = BLADE SURFACE'/1H0,31X,' RADIATING LINE NO.  1 BEGINS AT',
     1' DOWNSTREAM',
     1' INFINITY '/42X,' AND IS REPEATED AS LINE NO. ',I3)
      IF(ALLOUT)WRITE(6,13)
13    FORMAT(1H0,15X,'SURFACE ',74X,'FLOW     STATIC'/16X'CONTOUR    ',
     1'X/CX        Y/CX      ',
     1'   PHI       XVEL       YVEL     DENSITY      MACH       ANGLE',
     1'  PRES COEF'/15X,' NUMBER')
      IDEX=1
      ICOUNT=0
      DO 969 I=1,IEXIT
      I1M=I-1
      IF(I.GT.1.AND.ALLOUT)WRITE(6,14) I1M
14    FORMAT('ORADIATING LINE'/'     NUMBER ',I3)
      IM1= I-1
      IF(IM1.EQ.0) IM1=2
      FIRSTJ=1
      LINEI=I


C     DO (VELOCITY CALCULATION ALONG RADIATING LINE)
      CALL SPEEDS(LINEI,FIRSTJ)


969   CONTINUE
      DO 972 I=2,IEXIT
972   E(I)=.5*(DELPSV(I,4)+DELPSV(IEXIT+2-I,4))
      DO 975 I=2,IEXIT
975   DELPSV(I,4)=E(I)
      REWIND 13
      MM3=M-3
      NNOZ=NOZ-1

C      WRITE THE PLOT DATA SAVE FILE

      WRITE(13,1)  NNOZ,MM3
1     FORMAT(2I5)
      WRITE(13,2)((X(I,J),I=2,NZZ),J=4,M),((Y(I,J),I=2,NZZ),J=4,M)
      WRITE(13,2)((DUMBX(I,J),I=2,NZZ),J=4,M),((DUMBY(I,J),I=2,NZZ),
     1J=4,M),((DELPSV(I,J),I=2,NZZ),J=4,M)
      WRITE(13,2) ((TENOLF(I,J),I=2,NZZ),J=4,M)
```

```
      IF(BUG3)
     1WRITE(6,2)((X(I,J),I=2,NZZ),J=4,M),((Y(I,J),I=2,NZZ),J=4,M)
      IF(BUG3)
     1WRITE(6,2)((DUMBX(I,J),I=2,NZZ),J=4,M),((DUMBY(I,J),I=2,NZZ),
     1J=4,M)
C     END

      RETURN








      END
      SUBROUTINE SPEEDS(I,MM2)

C      VELOCITY CALCULATION ALONG ONE RADIATING LINE (I), BEGINNING AT J
C     =
C      MM2 AND GOING TO J=M (THE BLADE SURFACE).    ARRAYS DELPHI, DELPS
C     V
C      D,E,F,PRIORS,DUMBY, AND DUMBX ARE REUSED (OVERWRITTEN) IN THE PRO
C     CESS.




      LOGICAL INLET,BLADE,EXIT,BOTTOM,TOP
      LOGICAL DOSURF,SMOOTH,FINEST,RESTAR,ALLOUT
      REAL LAB,LAD,MINF,LENGTH,JACOB,LAMDAO
      REAL MACH(8)
      DOUBLE PRECISION CAPK,CAPKP
      COMMON/PARAM/RESTAR,NOZIN,BETA1,BETA2,QINF1,CI,CII,GAMMA,MINF,EM
     1,DELTA,BETA,TOL,BUG,BUG2,BUG3,IT,GUESS,OVEREL,FIXR,NOWREL,NOTYET
     1,DAMP,SUPREL,S,WAKE,B2OB1,UNDERL,RADRAT,RADLE,OMEGA,FLOCO,VAXIAL,
     1ALLOUT
      COMMON/QUASI/ RADIUS(100,30),HEIGHT(100,30)
      COMMON/ENTIRE/  X(100,30),Y(100,30),PHI(100,30),DELPSV(100,30)
      COMMON/GEOM2/ZETA(100),ETA(100)
      COMMON/CROSS/ ZMACH(100,30)
      COMMON/GEOM/NOZ,M,RLE,RTE,A,CHORD,XUPS,XDNS,LAMDAO,CC,CAPK,
     1CAPKP,PI
     1,RNK,VB,KN,NED,BB,DOSURF,RFAC,SOLID,MPLS
     1,STABAC,SLP1,SLP2,SLP3,SLP4,SMOOTH,CHOP,THETT,THETL
     1,FINEST
```

```
      COMMON/CALVEL/FAKEFI(4,6),FAKFI(4,6),RHOCON,QLIM,EXPO,ROTATN,
     1ROTROT,IM1,IEXIT,PRIORS(14,30),INDEX(100,30),I1DEX(32),FAKEU(100),
     1FAKEV(100),ICOUNT,IDEX,AMY,AMZ
      COMMON/VELOUT/D(100),E(100),F(100),DELPHI(100),TENOLF(100,30),
     1DUMBX(100,30),DUMBY(100,30),BOPR,FADBOP,XOCX,KK
      DIMENSION RHOSS(8), FI1(8),FI2(3),FI3(3),FI9(8),SPAN(8),
     1EMACH(100,30)
     2,COSX(8),COSY(8),LENGTH(8),DEDX(8),DZDX(8),DEDY(8),
     3DZDY(8),T(8),DPHIDZ(8),DPHIDE(8),U(8),V(8),UN(8),RHO(8),
     4RHOUL(8),ONOFF(8),DELPM1(3)
     5,HITE(8)

      COMMON/HIBALL/ SUPERG(46,30,100)

      XDIF(A,B,C,D)=.5*(A+B-C-D)




C     PROCEDURE (VELOCITY CALCULATION ALONG RADIATING LINE)
C     DO (AXIAL LOCATION INDICATORS)
      INLET=.FALSE.
      EXIT  = .FALSE.
      IF(I.EQ.1) INLET =.TRUE.
      IF( I.EQ. IEXIT) EXIT=.TRUE.
      XLOW=0.
      XHI =0.
      YLOW=1.E10
      DO 1111 I1=1,IEXIT
      IF(XLOW.LT.X(I1,M))GOTO11
      XLOW=X(I1,M)
11    IF(XHI.GT.X(I1,M))GOTO111
      XHI=X(I1,M)
111   IF(YLOW.LT.Y(I1,M))GOTO1111
      YLOW=Y(I1,M)
1111  CONTINUE
      DO 1427 J=MM2,M
      J3M=J-3
      JM1=J-1
      IF(JM1.EQ.0) JM1=2
C     DO (VERTICAL LOCATION INDICATORS)
      BOTTOM = .FALSE.
      TOP    = .FALSE.
      BLADE  = .FALSE.
      IF(J.EQ.1) BOTTOM =.TRUE.
      IF(J.EQ.M) TOP =.TRUE.
      BLADE = TOP
```

```
C     DO (GEOMETRY ADVANCE)                                              QS018730
      SPAN(1)=XDIF(RADIUS(I,J),RADIUS(I+1,J),0.,0.)                      QS018740
      IF(I.EQ.IEXIT)SPAN(1)=RADIUS(I,J)                                  QS018750
      SPAN(1)=SPAN(1)/FIXR                                               QS018760
      SPAN(2)=XDIF(RADIUS(I,J),RADIUS(I,J+1),0.,0.)                      QS018770
      SPAN(2)=SPAN(2)/FIXR                                               QS018780
      SPAN(3)=SPAN(2)                                                    QS018790
      SPAN(8)=SPAN(1)                                                    QS018800
      COSX(1)=SUPERG(1,J,I)                                              QS018810
      COSX(2)=SUPERG(2,J,I)                                              QS018820
      COSX(3)=SUPERG(3,J,I)                                              QS018830
      COSX(8)=SUPERG(4,J,I)                                              QS018840
      COSY(1)=SUPERG(5,J,I)                                              QS018850
      COSY(2)=SUPERG(6,J,I)                                              QS018860
      COSY(3)=SUPERG(7,J,I)                                              QS018870
      COSY(8)=SUPERG(8,J,I)                                              QS018880
      LENGTH(1)=SUPERG(9,J,I)                                            QS018890
      LENGTH(2)=SUPERG(10,J,I)                                           QS018900
      LENGTH(3)=SUPERG(11,J,I)                                           QS018910
      LENGTH(8)=SUPERG(12,J,I)                                           QS018920
      EXDIF1=SUPERG(13,J,I)                                              QS018930
      EXDIF2=SUPERG(14,J,I)                                              QS018940
      YDIF1=SUPERG(15,J,I)                                               QS018950
      YDIF2=SUPERG(16,J,I)                                               QS018960
      SLEN=SUPERG(17,J,I)                                                QS018970
      SLEN2=SUPERG(18,J,I)                                               QS018980
      ZETDF1=SUPERG(19,J,I)                                              QS018990
      ZETDF2=SUPERG(20,J,I)                                              QS019000
      ETADF1=SUPERG(21,J,I)                                              QS019010
      ETADF2=SUPERG(22,J,I)                                              QS019020
      DEDX(1)=SUPERG(23,J,I)                                             QS019030
      DEDX(2)=SUPERG(24,J,I)                                             QS019040
      DEDX(3)=SUPERG(25,J,I)                                             QS019050
      DEDX(8)=SUPERG(26,J,I)                                             QS019060
      DEDY(1)=SUPERG(27,J,I)                                             QS019070
      DEDY(2)=SUPERG(28,J,I)                                             QS019080
      DEDY(3)=SUPERG(29,J,I)                                             QS019090
      DEDY(8)=SUPERG(30,J,I)                                             QS019100
      DZDX(1)=SUPERG(31,J,I)                                             QS019110
      DZDX(2)=SUPERG(32,J,I)                                             QS019120
      DZDX(3)=SUPERG(33,J,I)                                             QS019130
      DZDX(8)=SUPERG(34,J,I)                                             QS019140
      DZDY(1)=SUPERG(35,J,I)                                             QS019150
      DZDY(2)=SUPERG(36,J,I)                                             QS019160
      DZDY(3)=SUPERG(37,J,I)                                             QS019170
      DZDY(8)=SUPERG(38,J,I)                                             QS019180
      T(1)=SUPERG(39,J,I)                                                QS019190
      T(2)=SUPERG(40,J,I)                                                QS019200
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      T(3)=SUPERG(41,J,I)                                              QS019210
      T(8)=SUPERG(42,J,I)                                              QS019220
C     CELL  II,  POINT  C                                              QS019230
      T(5) =  PRIORS(1,J)*ONOFF(5)                                     QS019240
      T(4) =  PRIORS(2,J)*ONOFF(4)                                     QS019250
      PRIORS(1,J) = - T(8)                                             QS019260
      PRIORS(2,J) = - T(1)                                             QS019270
C     DO (FIELD GRADIENTS)                                             QS019280
C     CELL II,  POINT C                                                QS019290
      DO 1214 I1=1,3                                                   QS019300
      FI1(I1)=PHI(I+1,J)                                               QS019310
      FI2(I1)=PHI(I+1,J+1)                                             QS019320
      FI3(I1)=PHI(I  ,J+1)                                             QS019330
1214  FI9(I1)=PHI(I  ,J  )                                             QS019340
      FI4    =PHI(IM1,J+1)                                             QS019350
      FI5    =PHI(IM1,J  )                                             QS019360
      FI6    =PHI(IM1,JM1)                                             QS019370
      FI7    =PHI(I  ,JM1)                                             QS019380
      FI8    =PHI(I+1,JM1)                                             QS019390
      FI1(8)=PHI(I+1,J)                                                QS019400
      FI9(8)=PHI(I  ,J)                                                QS019410
      I10=I-IEXIT+3                                                    QS019420
C     END                                                              QS019430
C     END                                                              QS019440
C     CELL I , POINT A                                                 QS019450
2501  DPHIDZ(1)= XDIF(FI3(1),FI2(1),FI9(1),FI1(1))/ZETDF1              QS019460
      DPHIDE(1) =  (FI1(1)-FI9(1))/ETADF1                              QS019470
C     CELL I, POINT B                                                  QS019480
      DPHIDE(2)=XDIF(FI1(2),FI2(2),FI9(2),FI3(2)) /ETADF1              QS019490
      DPHIDZ(2)=(FI3(2)-FI9(2))/ZETDF1                                 QS019500
C     CELL II, POINT B                                                 QS019510
      DPHIDE(3)=XDIF(FI5,FI4,FI9(3),FI3(3)) /ETADF2                    QS019520
      DPHIDZ(3)=(FI3(3)-FI9(3))/ZETDF1                                 QS019530
C     CELL IV, POINT A                                                 QS019540
      DPHIDE(8) =  (FI1(8)-FI9(8))/ETADF1                              QS019550
      DPHIDZ(8) =XDIF(FI7,FI8,FI9(8),FI1(8))/ZETDF2                    QS019560
C     DO (BOUNDARY CONDITION SWITCHES)                                 QS019570
      DO 1306 I1=1,8                                                   QS019580
1306  ONOFF(I1)=1.                                                     QS019590
      IF(.NOT.INLET.AND..NOT.BOTTOM.AND..NOT.TOP ) GOTO2060            QS019600
      IF(TOP)IS=1                                                      QS019610
      IF(INLET)IS=3                                                    QS019620
      IF(BOTTOM)IS=5                                                   QS019630
      IE=IS+3                                                          QS019640
      DO 2059 I1=IS,IE                                                 QS019650
2059  ONOFF(I1)=0.                                                     QS019660
C     DO (VELOCITIES AND DENSITIES)                                    QS019670
2060  U(6) = U(3)                                                      QS019680
```

```
      V(6) = V(3)                                                       QS019690
      U(7) = U(2)                                                       QS019700
      V(7) = V(2)                                                       QS019710
      DO 1337 I1 =1,8                                                   QS019720
      IF(I1.GE.4.AND.I1.NE.8) GOTO 1337                                 QS019730
C     IF(I1.LT.4.OR.I1.EQ.8) THEN                                       QS019740
      U(I1)=DPHIDE(I1)*DEDX(I1)+ DPHIDZ(I1)*DZDX(I1)                    QS019750
      V(I1)=DPHIDE(I1)*DEDY(I1)+ DPHIDZ(I1)*DZDY(I1)                    QS019760
      IF(INDEX(I,J).EQ.0)GOTO5411                                       QS019770
      ICOUNT=ICOUNT+1                                                   QS019780
      I1S=I1DEX(ICOUNT)                                                 QS019790
      IF(I1.LE.I1S)I1P=I1S                                              QS019800
      IDIF=INDEX(I,J)+I1S-1                                             QS019810
      IF(I1S.EQ.1.AND.I1P.EQ.IDIF)I1P=8                                 QS019820
      IF(I1.NE.I1P)GOTO5410                                             QS019830
      IF(I1P.GT.IDIF.AND.I1P.NE.8)GOTO5410                              QS019840
      V(I1)=FAKEV(IDEX)                                                 QS019850
      U(I1)=FAKEU(IDEX)                                                 QS019860
      IDEX=IDEX+1                                                       QS019870
      I1P=I1P+1                                                         QS019880
5410  IF(I1.NE.8)ICOUNT=ICOUNT-1                                        QS019890
5411  V(I1)=V(I1)-SPAN(I1)*FIXR/RADLE*ROTATN                            QS019900
      UN(I1)=U(I1)*COSX(I1)+V(I1)*COSY(I1)                              QS019910
C     END                                                               QS019920
1337  CONTINUE                                                          QS019930
      IF(.NOT.TOP) GOTO 2064                                            QS019940
C     IF(TOP) THEN                                                      QS019950
C     U(8)=(DPHIDE(8)*ETADF1-RADIUS(I,J)/RADLE*ROTATN*YDIF1)*EXDIF1/SLENQS019960
C     V(8)=(DPHIDE(8)*ETADF1-RADIUS(I,J)/RADLE*ROTATN*YDIF1)*YDIF1/SLEN QS019970
      ROTATX=ROTATN*RADIUS(I,J)/RADLE                                   QS019980
C     U8=SQRT((DPHIDE(8)*ETADF1/EXDIF1)**2+(DPHIDE(8)*ETADF1/YDIF1-     QS019990
C    1-ROTATX)**2)*EXDIF1/SQRT(SLEN)                                    QS020000
      U8=SQRT(U(8)*U(8)+V(8)*V(8))*ABS(EXDIF1)/SQRT(SLEN)               QS020010
      U(8)=SIGN(U8,U(8))                                                QS020020
      V(8)=U(8)*YDIF1/EXDIF1                                            QS020030
      UN(8)=U(8)*COSX(8)+V(8)*COSY(8)                                   QS020040
C     END                                                               QS020050
2064  U(4) =  PRIORS(3,J)                                               QS020060
      U(5) =  PRIORS(4,J)                                               QS020070
      V(4) =  PRIORS(5,J)                                               QS020080
      V(5) =  PRIORS(6,J)                                               QS020090
      PRIORS(3,J)=U(1)                                                  QS020100
      PRIORS(4,J)=U(8)                                                  QS020110
      PRIORS(5,J)=V(1)                                                  QS020120
      PRIORS(6,J)=V(8)                                                  QS020130
      RHO(7)=RHO(2)                                                     QS020140
      RHO(6)=RHO(3)                                                     QS020150
      RHO(4)=PRIORS(7,J)                                                QS020160
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      RHO(5)=PRIORS(8,J)                                                QS020170
      ONSUM=0.                                                          QS020180
      DO 1391 I1=1,8                                                    QS020190
C     IF(KK.LE.2.OR.MOD(KK,2).EQ.0) THEN                                QS020200
      IF(I1.GE.4.AND.I1.NE.8) GOTO 2066                                 QS020210
C     IF(I1.LT.4.OR.I1.EQ.8) THEN                                       QS020220
      RHOFAC=1.                                                         QS020230
      RHO(I1)=1.                                                        QS020240
      IF((I.EQ.2.OR.I.EQ.IEXIT).AND.J.LE.4.AND.ROTATN.NE.0.             QS020250
     1.OR.KK.LE.NOTYET) GOTO 2066                                       QS020260
      QSQAR=U(I1)*U(I1)+(V(I1)*V(I1))                                   QS020270
      IF(QSQAR.GE.QLIM)QSQAR=.99*QLIM                                   QS020280
      RHOFAC=RHOCON*(1.-QSQAR)*ONOFF(I1)+1.                             QS020290
      RHO(I1)=1.-AMZ*(QSQAR-1.)+AMY*(QSQAR-1.)*(QSQAR-1.)               QS020300
      IF(QSQAR.LT..65.OR.QSQAR.GT.1.44)RHO(I1)=RHOFAC**EXPO             QS020310
      ROTATX=SPAN(I1)*FIXR                                              QS020320
      IF(ROTROT.NE.0..AND.J.GT.3)                                       QS020330
     1RHO(I1)=(RHO(I1)**(1./EXPO)+RHOCON*ROTROT*((ROTATX/RADLE)         QS020340
     1**2-1.)*ONOFF(I1))**EXPO                                          QS020350
C     END                                                               QS020360
C     END                                                               QS020370
2066  QSQAR=U(I1)*U(I1)+V(I1)*V(I1)                                     QS020380
      IF(I.GT.1)                                                        QS020390
     1MACH(I1)=MINF*SQRT(QSQAR)/RHO(I1)**(1./EXPO)                      QS020400
      IF(MACH(I1).GT.2.)MACH(I1)=2.                                     QS020410
1391  CONTINUE                                                          QS020420
      PRIORS(7,J)=RHO(1)                                                QS020430
      PRIORS(8,J)=RHO(8)                                                QS020440
      IF(I.LE.1.OR.J.LE.3) GOTO 1427                                    QS020450
C     IF(I.GT.1.AND.J.GT.3) THEN                                        QS020460
      E(J)=1.                                                           QS020470
      F(J)=0.                                                           QS020480
      ONSUM=ONOFF(1)+ONOFF(8)+ONOFF(4)+ONOFF(5)                         QS020490
      E(J)=(U(1)*ONOFF(1)+U(8)*ONOFF(8)+U(4)*ONOFF(4)+U(5)              QS020500
     1*ONOFF(5))/ONSUM                                                  QS020510
      F(J)=(V(1)*ONOFF(1)+V(8)*ONOFF(8)+V(4)*ONOFF(4)+V(5)              QS020520
     1*ONOFF(5))/ONSUM                                                  QS020530
      DUMBX(I,J)=E(J)                                                   QS020540
      DUMBY(I,J)=F(J)                                                   QS020550
      EFFAC=1.-E(J)*E(J)-F(J)*F(J)                                      QS020560
      DELPHI(J)=(RHO(1)*ONOFF(1)+RHO(8)*ONOFF(8)+RHO(4)*ONOFF(4)+RHO(5) QS020570
     1*ONOFF(5))/ONSUM                                                  QS020580
      D(J)=0.                                                           QS020590
      D(J)=MINF*SQRT((F(J)*F(J)+E(J)*E(J))/DELPHI(J)**(1./EXPO))        QS020600
      IF(J.LE.6.AND.(I.LE.4.OR.I.GE.IEXIT-2)) D(J)=EM                   QS020610
      IF(J.LE.6.AND.I.GE.NOZ-1.AND.I.LE.NOZ+1)D(J)=MINF                 QS020620
      DELPSV(I,J)=D(J)                                                  QS020630
C     END                                                               QS020640
```

```
2076  IF(E(J).NE.0.)BOPS=ATAN2(F(J),E(J))*180./PI
      BOPR=-999.
      IF(D(J).NE.0.)
     1BOPR=2./GAMMA*(DELPHI(J)*(1.-EFFAC)/D(J)/D(J)-1./MINF/MINF)
      IF(MINF.LT..25)BOPR=1.+DELPHI(J)*(EFFAC-1.)
      XOCX=(X(I,J)-XLOW)/(XHI-XLOW)
      FADBOP=(Y(I,J)-YLOW)/(XHI-XLOW)
      IF(ALLOUT.AND.MM2.EQ.1)
     1WRITE(6,12) J3M,XOCX,FADBOP,PHI(I,J),E(J),F(J),DELPHI(J)
     1,D(J),BOPS,BOPR
      TENOLF(I,J)=BOPR
C     END
1427  CONTINUE
12    FORMAT(15X,I4,4X,9F10.5)
      RETURN
      END
      SUBROUTINE WRAPUP(ZETA,ETA,S)


C              GEOMETRY GENERATION FOR CASCADE POTENTIAL FLOW SOLVER



      LOGICAL DOSURF,SMOOTH,BUG2,ORTHO
      REAL LAMDAO
      COMPLEX H1,H2,ORIGIN,CDWISE
      COMPLEX AI/(0.,1.)/
      DOUBLE PRECISION CAPK,CAPKP
      DIMENSION ZETA(100),ETA(100),DUMBE(100),H1(100),H2(100)
      DIMENSION XB(200),YB(200),DUMBX(100,30)
      COMMON/ENTIRE/  X(100,30),Y(100,30),PHI(100,30),DUMBY(100,30)
      COMMON/GEOM/NOZ,M,RLE,RTE,A,CHORD,XUPS,XDNS,LAMDAO,CC,CAPK
     1,CAPKP,PI
     1,RNK,VB,KN,NED,BB,DOSURF,RFAC,SOLID,MPLS
     1,STABAC,SLP1,SLP2,SLP3,SLP4,SMOOTH,CHOP,THETT,THETL
      NAMELIST/INSTUF/H1,H2,IMAXY,BUG2
      DATA ORTHO/.FALSE./,BUG2/.FALSE./

      MAGIC=0
      MAGICM=0


      REWIND 18

C      RECORD OLD COMPUTATIONAL VARIABLES FOR INTERPOLATION IN FILPHI

      WRITE(18) ETA,ZETA
      PI=3.14159265
```

```
      SO=CHORD                                                          QS021130
                                                                        QS021140
C      IF(NOZ.LT.0) OBTAIN MESH FROM STORAGE FILE                       QS021150
                                                                        QS021160
      IF(NOZ.LE.0) GOTO201                                              QS021170
C     IF(NOZ.GT.0) GENERATE A NEW MESH                                  QS021180
      IEXIT=2*NOZ-1                                                     QS021190
      NZZ=IEXIT                                                         QS021200
      DOSURF=.TRUE.                                                     QS021210
      IF(NED.LE.0)DOSURF=.FALSE.                                        QS021220
      NED=IABS(NED)                                                     QS021230
      IF(DOSURF)READ(5,INSTUF,END=15)                                   QS021240
C     WRITE(6,12)                                                       QS021250
12    FORMAT(37HTHE FOLLOWING IS THE FIRST ECHO PRINT)                  QS021260
C     WRITE(6,INSTUF)                                                   QS021270
15    IF(DOSURF)READ(5,INSTUF,END=16)                                   QS021280
      WRITE(6,11)                                                       QS021290
11    FORMAT(38HTHE FOLLOWING IS THE SECOND ECHO PRINT)                 QS021300
      WRITE(6,INSTUF)                                                   QS021310
16    IF(KN.EQ.0)ORTHO=.TRUE.                                           QS021320
      IF(ORTHO) GOTO203                                                 QS021330
C     IF(.NOT.ORTHO) REARRANGE H2 INPUT INTO H1(UPPER SURFACE), AND H2(LQS021340
C     OWER SURFACE)                                                     QS021350
C      UNSTAGGERED DATA TABLES, FOR THE INTERPOLATION SCHEME            QS021360
                                                                        QS021370
      NEDKN1=NED-KN+1                                                   QS021380
      ORIGIN=H2(NEDKN1)                                                 QS021390
      DO 205 I1=1,KN                                                    QS021400
      I5=NED-KN+I1                                                      QS021410
      H1(I1)=H2(I5)                                                     QS021420
      CDWISE =(H1(I1)-ORIGIN)*CEXP(-AI*LAMDA0)                          QS021430
      H1(I1)=CDWISE                                                     QS021440
205   CONTINUE                                                          QS021450
      DO 206 I1=1,NEDKN1                                                QS021460
      I6=NED-KN-I1+2                                                    QS021470
      IF(I6.LE.0)I6=1                                                   QS021480
206   H1(KN+I1)=H2(I6)                                                  QS021490
      DO 209 I1=1,NEDKN1                                                QS021500
      H2(I1)=H1(KN+I1)                                                  QS021510
      CDWISE=(H2(I1)-ORIGIN)*CEXP(-AI*LAMDA0)                           QS021520
      H2(I1)=CDWISE                                                     QS021530
209   CONTINUE                                                          QS021540
      NED=NED+1                                                         QS021550
      GOTO233                                                           QS021560
                                                                        QS021570
                                                                        QS021580
C      IF(ORTHO) REARRANGE H2 INPUT TO START AT MINIMUM Y POINT RATHER TQS021590
C     HAN MAX X,                                                        QS021600
```

```
C        FOR ELECTROSTATIC ANALOG SCHEME

203     T2=1.E10
        IT2=0
        DO 2333 I1=1,NED
        IF(AIMAG(H2(I1)).GE.T2) GOTO2333
        IT2=I1
        T2=AIMAG(H2(IT2))
2333    CONTINUE
        DO 23333 I1=1,NED
        I7=IT2+I1-1
        IF(I7.EQ.NED)IT3=I1
        IF(I7.GT.NED)I7=I1-IT3+1
23333   H1(I1)=H2(I7)
        T2=-1.E10
        I2T=0
        DO 2033 I1=1,NED
        IF(AIMAG(H1(I1)).LE.T2)GOTO2033
        T2=AIMAG(H1(I1))
        I2T=I1
2033    H2(I1)=H1(I1)


        IMAXY=I2T

C        LOAD COMPLEX INPUT INTO XBOD AND YBOD ARRAYS

233     CONTINUE
        DO 213 K=1,NED
        KMKN=K-KN
        IF(K.GT.KN) GOTO217
C       IF(K.LE.KN) THEN
        XB(K)=REAL(H1(K))
        YB(K)=AIMAG(H1(K))
        GOTO213
217     XB(K)=REAL(H2(KMKN))
        YB(K)=AIMAG(H2(KMKN))
213     CONTINUE
        IF(CHORD.EQ.1.) GOTO219
C       IF(CHORD.NE.1.) NORMALIZE COORDINATES TO AERODYNAMIC CHORD
        DO 221 I2=1,NED
        XB(I2)=XB(I2)/CHORD
221     YB(I2)=YB(I2)/CHORD
        RLE=RLE/CHORD
        RTE=RTE/CHORD
        S=S/CHORD
        CHORD=1.
C       END
```

```
219   IF(.NOT.ORTHO) GOTO225
C     IF(ORTHO) DO ELECTROSTATIC ANALOG GRID

      DO 227 I2=1,NED
227   H1(I2)=CMPLX(XB(I2),YB(I2))
      WRITE(6,9)
9     FORMAT(1H1,40X,' ELECTROSTATIC ANALOG GRID GENERATED')
      CALL PJGRID(ZETA,ETA,H1,IMAXY,S)
      GOTO226


C      OTHERWISE DO INTERPOLATION SCHEME GRID

225   WRITE(6,10)
10    FORMAT(1H1,40X,' INTERPOLATION SCHEME GRID GENERATED')
      CALL GRIDDL(ZETA,ETA,XB,YB,S)

C      WRITE MESH POINTS STORAGE FILE

226   WRITE(13,1) NOZ,M,KN,NED
      WRITE(13,2)((X(I,J),I=1,NZZ),J=1,M),((Y(I,J),I=1,NZZ),J=1,M)
     1,(ETA(I),I=1,NZZ),(ZETA(J),J=1,M)



      GOTO202


C      FOR EXISTING MESH FILES, NORMALIZE PARAMETERS AND READ FILE

201   IF(CHORD.EQ.1.) GOTO231
C     IF(CHORD.NE.1.) THEN
      RLE=RLE/CHORD
      PTE=RTE/CHORD
      S=S/CHORD
      CHORD=1.
C     END
231   READ(23,1) NOZZ,MM,KN,NED
      MAGIC=IABS((NOZZ-1)/(NOZ+1))
      MAGICM=(MM-1)/(M-1)
      M=MM
      NOZ=NOZZ
      IEXIT=2*NOZ-1
      NZZ=IEXIT
      READ(23,2)((X(I,J),I=1,NZZ),J=1,M),((Y(I,J),I=1,NZZ),J=1,M)
```

```
     1,(ETA(I),I=1,NZZ),(ZETA(J),J=1,M)

C      IF FINEST MESH IS DESIRED, SKIP SELECTION PROCESS

      IF(MAGIC.LE.1.AND.MAGICM.LE.1) GOTO202
C     IF(MAGIC.GT.1.OR.MAGICM.GT.1) SELECT AND LOAD GRID LINES DESIRED T
C     O FORM
C      A COARSE MESH
      DO 235 J=1,M,MAGICM
      JON=(J-1)/MAGICM+1
      ZETA(JON)=ZETA(J)
      DO 239 I=1,NZZ,MAGIC
      ION=(I-1)/MAGIC+1
      DUMBX(ION,JON)=X(I,J)
239   DUMBY(ION,JON)=Y(I,J)
      IF(MOD(ION,2).EQ.0) ION=ION-1

C      RADIATING LINE TO UPSTREAM INFINITY MUST BE INCLUDED
      DUMBX(ION,JON)=X(NZZ,J)
      DUMBY(ION,JON)=Y(NZZ,J)

      NOZZ=(ION+1)/2

C      RADIATING LINE TO DOWNSTREAM INFINITY MUST BE INCLUDED
      DUMBX(NOZZ,JON)=X(NOZ,J)
235   DUMBY(NOZZ,JON)=Y(NOZ,J)

      DO 243 I=1,ION
      IOLD=(I-1)*MAGIC+1
      ETA(I)=ETA(IOLD)

C      BLADE SURFACE MUST BE LAST CLOSED CURVE
      DUMBX(I,JON)=X(IOLD,M)
      DUMBY(I,JON)=Y(IOLD,M)

C      PERIODIC BOUNDARY MUST BE FIRST CLOSED CURVE
      DUMBX(I,1)=X(IOLD,1)
243   DUMBY(I,1)=Y(IOLD,1)

      DUMBX(ION,JON)=X(NZZ,M)
      DUMBY(ION,JON)=Y(NZZ,M)
      DUMBX(ION,1)=X(NZZ,1)
      DUMBY(ION,1)=Y(NZZ,1)
      DUMBX(NOZZ,M)=X(NOZ,M)
      DUMBY(NOZZ,M)=Y(NOZ,M)
      DUMBY(NOZZ,1)=Y(NOZ,1)
      DUMBX(NOZZ,1)=X(NOZ,1)
```

```
      DO 251 J=1,JON
      DO 251 I=1,ION
      X(I,J)=DUMBX(I,J)
251   Y(I,J)=DUMBY(I,J)
      ZETA(JON)=ZETA(M)
      ETA(ION)=ETA(NZZ)
      ETA(NOZZ)=ETA(NOZ)
      NZZ=ION
      IEXIT=NZZ
      NOZ=NOZZ
      M=JON
C      END OF SELECTION PROCESS
202   CONTINUE
      IF(.NOT.BUG2) GOTO255
C     IF(BUG2) THEN
      WRITE( 6,3) NOZ,M,KN,NED
3     FORMAT('0NOZ= ',I3,' M= ',I3,' KN= ',I3,' NED= ',I3)
      NEDM1=NED-1
C      FOR A NEW GEOMETRY GENERATION, CALCULATE THE SECOND DERIVATIVES O
C     N BLADE
C      SURFACE USING SMOOTHED INPUT COORDINATES
      DO 257 I=2,NEDM1
      DUMBX(I,15)=1.E06
      IF(XB(I).NE.XB(I-1).AND.XB(I).NE.XB(I+1).AND.
     1XB(I+1).NE.XB(I-1))
     1DUMBX(I,15)=((YB(I+1)-YB(I))/(XB(I+1)-XB(I))-(YB(I)-YB(I-1))/
     1(XB(I)-XB(I-1)))/(XB(I+1)-XB(I-1))*2.
257   CONTINUE
      WRITE(6,5)
      WRITE(6,55)
5     FORMAT(1H0,35X,'SMOOTHED BLADE SURFACE INPUT, HORIZONTAL CHORD')
55    FORMAT(1H0,35X,'  I        X              Y           2ND DERIV.   '/)
6     FORMAT(1H0,20X,'X GRID POINTS, AS STORED ON MESH FILE'/)
7     FORMAT(1H0,20X,'Y GRID POINTS, AS STORED ON MESH FILE'/)
4     FORMAT(35X,I4,3E13.5)
      WRITE(6,4) (I,XB(I),YB(I),DUMBX(I,15),I=1,NED)
      WRITE(6,6)
      WRITE(6,2)((X(I,J),I=1,NZZ),J=1,M)
      WRITE(6,7)
```

```
      WRITE(6,2) ((Y(I,J),I=1,NZZ),J=1,M)                               QS023530
1     FORMAT(4I5)                                                       QS023540
14    FORMAT(1H ,14E9.3)                                                QS023550
2     FORMAT(6E13.5)                                                    QS023560
                                                                        QS023570
                                                                        QS023580
                                                                        QS023590
255   IF(KN.NE.0)GOTO 261                                               QS023600
C     IF(ORTHO) TRANSLATE THE ORIGIN OF X POINTS TO MIDCHORD (INTERP SCHQS023610
C     EME                                                               QS023620
C      ALREADY TRANSLATED                                               QS023630
                                                                        QS023640
      DO 263 I1=1,NZZ                                                   QS023650
      DO 263 J1=1,M                                                     QS023660
263   X(I1,J1)=X(I1,J1)-.5                                              QS023670
                                                                        QS023680
C      REARRANGE (X,Y) TABLES SO THAT X(2,J),Y(2,J) AND X(NZZ+1,J),Y(NZZQS023690
C     +1,J) GO                                                          QS023700
C      TO DOWNSTREAM INFINITY, AND X(NOZ+1,J),Y(NOZ+1,J) GOES TO UPSTREAQS023710
C     M INFINITY                                                        QS023720
C      NUMBERING THE LINES CLOCKWISE AROUND THE BLADE.  AT PRESENT, LINEQS023730
C      1 GOES                                                           QS023740
C      TO UPS. INF.,  NOZ GOES TO DOWNS. INF. AND NZZ TO UPS. INF.      QS023750
C                                                                       QS023760
C      ALSO REALIGN ETA SO THAT VALUES WILL GO FROM ZERO (LINE 2) TO 2*CQS023770
C     APKP (LINE                                                        QS023780
C      NZZ+1), INSTEAD OF -CAPKP (LINE 1)  TO +CAPKP (LINE NZZ).        QS023790
                                                                        QS023800
261   DO 271 I1=1,NOZ                                                   QS023810
      DO 271 J1=1,M                                                     QS023820
      I2=I1+NOZ-1                                                       QS023830
      DUMBE(I1)=-ETA(I2)                                                QS023840
      DUMBX(I1,J1)=X(I1,J1)                                             QS023850
      DUMBY(I1,J1)=Y(I1,J1)                                             QS023860
      X(I1,J1)=X(I1+NOZ-1,J1)                                           QS023870
271   Y(I1,J1)=Y(I1+NOZ-1,J1)                                           QS023880
      NOZP1=NOZ+1                                                       QS023890
      DO 279 I1=NOZP1,NZZ                                               QS023900
      DO 279 J1=1,M                                                     QS023910
      I2=I1-NOZ+1                                                       QS023920
      DUMBE(I1)=-ETA(I2)+2.*ETA(1)                                      QS023930
      DUMBX(I1,J1)=X(I1,J1)                                             QS023940
      DUMBY(I1,J1)=Y(I1,J1)                                             QS023950
      X(I1,J1)=DUMBX(I1-NOZ+1,J1)                                       QS023960
279   Y(I1,J1)=DUMBY(I1-NOZ+1,J1)                                       QS023970
                                                                        QS023980
C      MOVE ALL VALUES UP 3 LOCATIONS IN J TO MAKE ROOM FOR 3 DUMMY ELLIQS023990
C     PSES                                                              QS024000
```

```
C       BEYOND THE PERIODIC LINE.

        I1=IEXIT
2088    IF(I1.LT.1)GOTO2872
2955    J1=M
2087    IF(J1.LT.1)GOTO2871
        X(I1,J1+3)= X(I1,J1)
        IF(I1.EQ.1)ZETA(J1+3)=ZETA(J1)
287     Y(I1,J1+3)= Y(I1,J1)
        J1=J1-1
        GOTO2087
2871    I1=I1-1
        GOTO2088


C       FINISH LOADING ETA; CREATE 3 DUMMY LINES USING PERIODIC RELATION
C       OF X,Y VALUES

2872    I1=IEXIT
295     IF(I1.LT.2)GOTO2951
        ETA(I1)=DUMBE(I1)
        DO 299 J1=1,3
        SIGEN=1.
        IF(I1.LT.NOZ)SIGEN=-1.
        IF(I1.EQ.NOZ)SIGEN=0.
        X(I1,J1)=X( IEXIT-I1+1 ,8-J1)+S*SIN(LAMDAO) *SIGEN
        IF(I1.EQ.2)ZETA(J1)=-ZETA(8-J1)
299     Y(I1,J1)=Y( IEXIT-I1+1 ,8-J1)+S*COS(LAMDAO)*SIGEN
        ETA(I1+1)=ETA(I1)


C       LOAD SPECIAL POINTS (J=4 NOW EQUALS PERIODIC LINE POINTS)

        I1=I1-1
        GOTO 295
2951    ETA(2)=0.
        ETA(IEXIT+1)=2.*ETA(1)
        X(IEXIT,1)=2.*X(IEXIT,4)
        X(IEXIT,2)=1.5*X(IEXIT,4)
        X(IFXIT,3)=1.2*X(IEXIT,4)
        Y(IEXIT,1)=2.*Y(IEXIT,4)
        Y(IEXIT,2)=1.5*Y(IEXIT,4)
        Y(IFXIT,3)=1.2*Y(IEXIT,4)
        X(NOZ,1)=2.*X(NOZ,4)
        X(NOZ,2)=1.5*X(NOZ,4)
        X(NOZ,3)=1.2*X(NOZ,4)
        Y(NOZ,1)=2.*Y(NOZ,4)
        Y(NOZ,2)=1.5*Y(NOZ,4)
```

```
      Y(NOZ,3)=1.2*Y(NOZ,4)
      MP3=M+3

C      MOVE ALL DATA UP ONE I LOCATION TO MAKE ROOM FOR A REPEATED RADIA
C     TING LINE
C      NEXT TO DOWNSTREAM INFINITY LINE .

      DO 2103 J1=1,MP3
      I1=IEXIT
2107  IF(I1.LT.1)GOTO21071
      X(I1+1, J1)=X(I1,J1)
      Y(I1+1, J1)=Y(I1,J1)
      DUMBX(I1,J1)=0.
      DUMBY(I1,J1)=0.
      I1=I1-1
      GOTO2107
21071 X(2,J1)=X(IEXIT+1,J1)
      Y(2,J1)=Y(IEXIT+1,J1)
      X(1,J1)=X(IEXIT  ,J1)
      Y(1,J1)=Y(IEXIT  ,J1)
      X(IEXIT+2,J1)=X(3,J1)
2103  Y(IEXIT+2,J1)=Y(3,J1)


      ETA(IEXIT+2)=ETA(3)+2.*ETA(1)
      ETA(1)=-ETA(3)

C      UPDATE COUNTERS

      NZZ=NZZ+1
      IEXIT=IEXIT+1
      NOZ=NOZ+1
      M=M+3


      ZETA(M+1)=ZETA(M)+ZETA(M)-ZETA(M-1)
      I67=M-14+1
      I67=MAXO(I67,1)
      I671=I67+1



      IF(.NOT.BUG2) RETURN

C      FOR NEW GEOMETRY GENERATIONS, CALCULATE SECOND DERIVATIVES ON BLA
C     DE SURFACE
C      USING THE FINAL GRID POINTS.
```

```
      NZZM1=NZZ-1
      DO 2113 I=2,NZZM1
      DUMBX(I,15)=1.E06
      IF(X(I,M).NE.X(I-1,M).AND.X(I,M).NE.X(I+1,M).AND.
     1X(I+1,M).NE.X(I-1,M))DUMBX(I,15)=
     1((Y(I+1,M)-Y(I,M))/(X(I+1,M)-X(I,M))-(Y(I,M)-Y(I-1,M))/
     1(X(I,M)-X(I-1,M)))/(X(I+1,M)-X(I-1,M))*2.
 2113 CONTINUE


      WRITE(6,8)
 8    FORMAT(1H0,30X,' GRID OUTPUT POINTS ON BLADE SURFACE, ',
     1'HORIZONTAL CHORD'//36X'   I          X                   Y',
     1'          2ND DERIV.   '/)
      DO 2119 I=2,NZZM1
      I1M=I-1
 2119 WRITE(6,4) I1M,X(I,M),Y(I,M),DUMBX(I,15)
      BUG2=.FALSE.




      RETURN
      END
      SUBROUTINE GRIDDL(ET,ZET,XBOD,YBOD,S)

C                    INTERPOLATION SCHEME GRID GENERATOR



C       IF(STAG.NE.0) DO (INTERMEDIATE TRANSFORM SETUP, ZERO STAG, S=2PI)
C       DO (CALCULATION OF GEOMETRY CONSTANTS)
C       DO (KNOWN GRID COORDINATES, ET, ZET)
C            IF(SLP2.LT.0) THEN
C                 DO (FLATPLATE-ZERO STAGGER TRANSFORM, UPPER SURFACE)
C                 DO (FLATPLATE-ZERO STAGGER TRANSFORM, LOWER SURFACE)
C                 CALL TOSTAG(S,ZET,CHORD)
C            DO (CONCENTRATION OF RADIATING LINES, ZET)
C            DO (CONCENTRATION OF SURFACE CONTOURS, ET)
C       DO (FLATPLATE-ZERO STAGGER TRANSFORM, UPPER SURFACE)
C       DO (FLATPLATE-ZERO STAGGER TRANSFORM, LOWER SURFACE)
C       DO (SPECIAL POINTS)
C       DO (CIRCLE TRANSFM. FROM ZERO STAGGER TO INPUT VALUES)
C       DO (RECALCULATION OF GEOMETRY CONSTANTS)
C       DO (TRANSLATE ORIGIN OF INPUT BODY POINTS TO MIDCHORD)
C       DO (TRAILING EDGE FIX OF EXTRA CAMBER POINTS)
```

```
C       DO (ADDITION OF BLADE SURFACE ON CLEAN FLATPLATE MESH)
C       RETURN



      DIMENSION  ET(100),ZET(100),XBOD(200)    ,YBOD(200)
      REAL  K,LNK,M1,LAM,LAMDA0,M
      INTEGER ZNO,ENO,ZN2M1,ZN2,END,ENOPLS,CAMBER,ZNP1,ENOP1
      DOUBLE PRECISION MMDELK
      DOUBLE PRECISION  CAPK,CAPKP,DM,DM1
      LOGICAL DOSURF,SMOOTH
      COMMON/ENTIRE/  X(100,30),Y(100,30)
      COMMON/GEOM/ZNO,ENO,RLE,RTE,A,CHORB,XUPS,XDNS,STAG,CC,CAPK
     1,CAPKP,PI
     1,LNK,M1,KM,END,M,DOSURF,R,SOLID,ENOPLS
     1,STABAC,SLP1,SLP2,SLP3,SLP4,SMOOTH,DUMBO(5),CAMBER
      XUPS=-1.E+01
      XDNS=1.E+01
      PI=3.14159265
      DELTA=0.
      ZNP1=ZNO+1
      LAMDA0=STAG
555   FORMAT(1H ,2E12.5)
      ENOPLS=ENO+ENO/CAMBER
      CHORD=CHORB-RLE/2.-RTE/2.
      XDNS= 25.*CHORD
      XUPS=-25.*CHORD
      SOLID=CHORB/S
      SOLFLT=CHORD/S
      SOLIDO=SOLFLT
      IF(STAG.EQ.0.)GOTO3002


C     DO (INTERMEDIATE TRANSFORM SETUP, I.E. ZERO STAG, S=2PI)

C     PROCEDURE (INTERMEDIATE TRANSFORM SETUP, I.E. ZERO STAG, S=2PI)
      ASTAG=ABS(STAG)
      CALL ALTERP(SOLFLT,ASTAG,ALFA,R)
      CHORD=ALOG((R*R+2.*R+1.)/(R*R-2.*R+1.))*2.
      SOLIDO=CHORD/PI/2.
      S=2.*PI
      LAMDA0=0.
C     END

3002  CONTINUE
```

```
C       DO (CALCULATION OF GEOMETRY CONSTANTS)

C       PROCEDURE (CALCULATION OF GEOMETRY CONSTANTS)
        A= COS(LAMDAO)/2./SOLIDO
        K= EXP(-PI/2./A)
        LNK = -ALOG(K)
        M=K*K
        DM=M
        DM1=1.DO-DM
        M1=DM1
        CAPK=MMDELK(1,DM,IER)
        CAPKP=MMDELK(1,DM1,IER)
C       END



C       DO (KNOWN GRID COORDINATES, ET,ZET)

C       PROCEDURE (KNOWN GRID COORDINATES, ET,ZET)
        DELZ=CAPKP/(ZNO-1)
        DELE=CAPK*STABAC/(ENO-1)
        ZN2M1=2*ZNO-1
        ZET(1)=+CAPKP
        DO 217  NZ=2,ZN2M1
217     ZET(NZ)=ZET(NZ-1)-DELZ
        ET(1)=0.
        ZN2 =  2*ZNO
        DO 221  NE=2,ENOPLS
221     ET(NE)=ET(NE-1)+DELE
        ET(ENO)=STABAC*CAPK
        ZET(ZNO)=0.
        IF(SLP1.GE.0.)GOTO205


C       IF(SLP1.LT.0.) DO (CONCENTRATION OF GRID LINES IN KEY AREAS)
C       PROCEDURE (CONCENTRATION OF GRID LINES IN KEY AREAS)
        XTES=-1.E19
        ITS=1
        SLP1=-SLP1


C        IF SLP2.LT.0 SETUP THE PROPER STAGGERED FLATPLATE MESH TO FIND WH
C       ICH LINE
C        INTERSECTS T. E.


        IF(SLP2.GE.0..OR.S.NE.2.*PI) GOTO226
        DELTA=ABS(SLP2)
```

```
C       DO (FLATPLATE-ZERO STAGGER TRANSFM. E,Z-X,Y UPPER SURFACE)
C       PROCEDURE (FLATPLATE-ZERO STAGGER TRANSFM. E,Z-X,Y UPPER SURFACE)
        DO 2060 I=1,ZNO
        DO 2060 J=1,ENOPLS
        IF((I.EQ.1.OR.I.EQ.ZNO).AND.J.EQ.1) GOTO2060
        ETER=ET(J)

C       DO (YOUR BASIC TRANSFORMATION )
C       PROCEDURE (YOUR BASIC TRANSFORMATION )
        ZED=ZET(I)
        IF(ETER.GT.CAPK)ZED=-ZED
        IF(ETER.GT.CAPK) ETER=2.*CAPK-ETER
        IF(I.EQ.ZNO)ZED=0.
        ALLFNC=FUDS(ETER, ZED,M1)
        LAM  = BADZAC(M1)
        TH   = OWOW(M1)
        X(I,J)= CHORD*A/PI*(LNK-2.*ALOG(ALLFNC/LAM))
        IF(J.GT.ENO.AND.I.EQ.ZN2M1)X(I,J)=-CHORD-X(I,J)
        IF(J.GT.ENO.AND.I.EQ.ZNO)X(I,J)=CHORD-X(I,J)
        Y(I,J)= 2.*A*CHORD/PI*TH
        IF(X(I,J).GT.XDNS)X(I,J)=XDNS
        IF(X(I,J).LT.XUPS)X(I,J)=XUPS
C       END

2060    CONTINUE
C       END

C       DO (FLATPLATE-ZERO STAGGER TRANSFM. E,Z-X,Y LOWER SURFACE)
C       PROCEDURE (FLATPLATE-ZERO STAGGER TRANSFM. E,Z-X,Y LOWER SURFACE)
        DO 2071 I=ZNP1,ZN2M1
        IDIF=I-ZNO
        X(I,1)=X(ZNO-IDIF,1)-S*SIN(LAMDAO)
        Y(I,1)= -A*CHORD
        DO 2071 J=1,ENOPLS
        IF(I.EQ.ZN2M1.AND.J.EQ.1) GOTO2071
        ETER=ET(J)

C       DO (YOUR BASIC TRANSFORMATION )
C       PROCEDURE (YOUR BASIC TRANSFORMATION )
        ZED=ZET(I)
        IF(ETER.GT.CAPK)ZED=-ZED
        IF(ETER.GT.CAPK) ETER=2.*CAPK-ETER
        IF(I.EQ.ZNO)ZED=0.
        ALLFNC=FUDS(ETER, ZED,M1)
        LAM  = BADZAC(M1)
        TH   = OWOW(M1)
        X(I,J)= CHORD*A/PI*(LNK-2.*ALOG(ALLFNC/LAM))
```

```
      IF(J.GT.ENO.AND.I.EQ.ZN2M1)X(I,J)=-CHORD-X(I,J)
      IF(J.GT.ENO.AND.I.EQ.ZNO)X(I,J)=CHORD-X(I,J)
      Y(I,J)= 2.*A*CHORD/PI*TH
      IF(X(I,J).GT.XDNS)X(I,J)=XDNS
      IF(X(I,J).LT.XUPS)X(I,J)=XUPS
C     END

2071  CONTINUE
C     END

      CALL TOSTAG(S,ZET,CHORD)
      DO 234 I3=1,ZN2M1
      IF(X(I3,ENO).LE.XTES) GOTO234
C     WRITE(6,4445) XTES,I3,X(I3,ENO)
4445  FORMAT(E13.5,I6,E13.5)
      XTES=X(I3,ENO)
      ITS=I3
234   CONTINUE
      EF=ZET(ITS)/CAPKP
      IF(SLP1.EQ.10.) EF=1.-EF
      SLP1=(1.-DELTA/EF/EF*(.6667-.2/EF/EF))/
     1(1.-1./EF/EF*(.6667-.2/EF/EF))
      SLP2=3.-SLP1*(2.-1./2.5/EF**4)-DELTA/2.5/EF**4
226   CONTINUE

C      CONCENTRATE THE RADIATING LINES  (COMPUTATIONAL COORD ZET)

C     DO (CONCENTRATION POLYNOMIAL)
C     PROCEDURE (CONCENTRATION POLYNOMIAL)
      CON1=2.5*(1.-SLP1)/CAPKP**2
      CON2=(SLP2-SLP1)/(2.*CAPKP**2)
      CON1=CON1-CON2
      CON3=(SLP2-SLP1)/(2.*CAPKP**4)
      CON4=1.5*(1.-SLP1)/(CAPKP**4)
      CON3=CON3-CON4
C     END

      DO 237 I3=1,ZN2M1
      CAPFAC=0.
      ZETER1=ZET(I3)
237   ZET(I3)=SLP1*ZETER1+CON1*ZETER1**3+CON3*ZETER1**5-CAPFAC
      IF(DELTA.EQ.0.) GOTO241
      EF=1.-EF
      SLP1=(1.-DELTA/EF/EF*(.6667-.2/EF/EF))/
     1(1.-1./EF/EF*(.6667-.2/EF/EF))
      SLP2=3.-SLP1*(2.-1./2.5/EF**4)-DELTA/2.5/EF**4
```

```
C       DO (CONCENTRATION POLYNOMIAL)                                           QS027370
C       PROCEDURE (CONCENTRATION POLYNOMIAL)                                    QS027380
        CON1=2.5*(1.-SLP1)/CAPKP**2                                             QS027390
        CON2=(SLP2-SLP1)/(2.*CAPKP**2)                                          QS027400
        CON1=CON1-CON2                                                          QS027410
        CON3=(SLP2-SLP1)/(2.*CAPKP**4)                                          QS027420
        CON4=1.5*(1.-SLP1)/(CAPKP**4)                                           QS027430
        CON3=CON3-CON4                                                          QS027440
C       END                                                                     QS027450
                                                                                QS027460
                                                                                QS027470
C        CONCENTRATE THE SURFACE CONTOURS (COMPUTATIONAL COORD ET)              QS027480
                                                                                QS027490
        DO 244 I3=1,ZN2M1                                                       QS027500
        CAPFAC=0.                                                               QS027510
        ZETER1=ZET(I3)                                                          QS027520
244     ZET(I3)=SLP1*ZETER1+CON1*ZETER1**3+CON3*ZETER1**5-CAPFAC                QS027530
241     CON5=2.5*(1.-SLP3)/CAPK**2                                              QS027540
        CON6=(SLP4-SLP3)/(2.*CAPK**2)                                           QS027550
        CON5=CON5-CON6                                                          QS027560
        CON7=(SLP4-SLP3)/2/CAPK**4                                              QS027570
        CON8=1.5*(1.-SLP3)/CAPK**4                                              QS027580
        CON7=CON7-CON8                                                          QS027590
        DO 248 J3=1,ENOPLS                                                      QS027600
        IF(J3.GT.ENO)ET(J3)=2.*CAPK-ET(J3)                                      QS027610
        ET(J3)=SLP3*ET(J3)+CON5*ET(J3)**3+CON7*ET(J3)**5                        QS027620
        IF(J3.GT.ENO)ET(J3)=2.*CAPK-ET(J3)                                      QS027630
248     CONTINUE                                                                QS027640
        SLP1=-SLP1                                                              QS027650
        IF(DELTA.NE.0.)SLP2=-DELTA                                              QS027660
4446    FORMAT(6E13.5)                                                          QS027670
C       END                                                                     QS027680
                                                                                QS027690
                                                                                QS027700
                                                                                QS027710
                                                                                QS027720
C       END OF CONCENTRATION PROCEDURE                                          QS027730
                                                                                QS027740
                                                                                QS027750
                                                                                QS027760
205     X(1,1)=XUPS                                                             QS027770
        X(ZNO,1)=XDNS                                                           QS027780
        X(ZN2M1,1)=XUPS                                                         QS027790
        NZNOM1=ZNO-1                                                            QS027800
                                                                                QS027810
                                                                                QS027820
C       DO (FLATPLATE-ZERO STAGGER TRANSFM. E,Z-X,Y UPPER SURFACE)              QS027830
                                                                                QS027840
```

```
C       PROCEDURE (FLATPLATE-ZERO STAGGER TRANSFM. E,Z-X,Y UPPER SURFACE)
        DO 260 I=1,ZNO
        DO 260 J=1,ENOPLS
        IF((I.EQ.1.OR.I.EQ.ZNO).AND.J.EQ.1) GOTO260
        ETER=ET(J)

C       DO (YOUR BASIC TRANSFORMATION )
C       PROCEDURE (YOUR BASIC TRANSFORMATION )
        ZED=ZET(I)
        IF(ETER.GT.CAPK)ZED=-ZED
        IF(ETER.GT.CAPK) ETER=2.*CAPK-ETER
        IF(I.EQ.ZNO)ZED=0.
        ALLFNC=FUDS(ETER, ZED,M1)
        LAM   = BADZAC(M1)
        TH    = OWOW(M1)
        X(I,J)= CHORD*A/PI*(LNK-2.*ALOG(ALLFNC/LAM))
        IF(J.GT.ENO.AND.I.EQ.ZN2M1)X(I,J)=-CHORD-X(I,J)
        IF(J.GT.ENO.AND.I.EQ.ZNO)X(I,J)=CHORD-X(I,J)
        Y(I,J)= 2.*A*CHORD/PI*TH
        IF(X(I,J).GT.XDNS)X(I,J)=XDNS
        IF(X(I,J).LT.XUPS)X(I,J)=XUPS
C       END

260     CONTINUE
C       END

        ZNP1=ZNO+1
        FK=1./SQRT(K)
        NZN2M2=ZN2M1-1


C       DO (FLATPLATE-ZERO STAGGER TRANSFM. E,Z-X,Y LOWER SURFACE)

C       PROCEDURE (FLATPLATE-ZERO STAGGER TRANSFM. E,Z-X,Y LOWER SURFACE)
        DO 271 I=ZNP1,ZN2M1
        IDIF=I-ZNO
        X(I,1)=X(ZNO-IDIF,1)-S*SIN(LAMDAO)
        Y(I,1)= -A*CHORD
        DO 271 J=1,ENOPLS
        IF(I.EQ.ZN2M1.AND.J.EQ.1) GOTO271
        ETER=ET(J)

C       DO (YOUR BASIC TRANSFORMATION )
C       PROCEDURE (YOUR BASIC TRANSFORMATION )
        ZED=ZET(I)
        IF(ETER.GT.CAPK)ZED=-ZED
        IF(ETER.GT.CAPK) ETER=2.*CAPK-ETER
```

```
      IF(I.EQ.ZNO)ZED=0.
      ALLFNC=FUDS(ETER, ZED,M1)
      LAM  = BADZAC(M1)
      TH   = OWOW(M1)
      X(I,J)= CHORD*A/PI*(LNK-2.*ALOG(ALLFNC/LAM))
      IF(J.GT.ENO.AND.I.EQ.ZN2M1)X(I,J)=-CHORD-X(I,J)
      IF(J.GT.ENO.AND.I.EQ.ZNO)X(I,J)=CHORD-X(I,J)
      Y(I,J)= 2.*A*CHORD/PI*TH
      IF(X(I,J).GT.XDNS)X(I,J)=XDNS
      IF(X(I,J).LT.XUPS)X(I,J)=XUPS
C     END

271   CONTINUE
C     END

C     DO (SPECIAL POINTS)

C     PROCEDURE (SPECIAL POINTS)
      DO 278 J=1,ENOPLS
      X(1,J)=X(ZN2M1,J)
      Y(ZN2M1,J)=0.
      Y(ZNO,J)  =0.
278   Y(1,J)  =0.
C     END


      IF(STAG.EQ.0.)  GOTO 209

C     DO (CIRCLE TRANSFM. FROM ZERO STAGGER TO INPUT VALUES)   .

C     PROCEDURE (CIRCLE TRANSFM. FROM ZERO STAGGER TO INPUT VALUES)
      CALL TOSTAG(S,ZET,CHORD)
      CHORD=CHORB-RTE/2.-RLE/2.
      LAMDAO=STAG
      SOLIDO=SOLFLT
      S=CHORD/SOLFLT
      OLDK=CAPK
      OLDKP=CAPKP

C     DO (CALCULATION OF GEOMETRY CONSTANTS)
C     PROCEDURE (CALCULATION OF GEOMETRY CONSTANTS)
      A= COS(LAMDAO)/2./SOLIDO
      K= EXP(-PI/2./A)
      LNK = -ALOG(K)
      M=K*K
      DM=M
```

```
      DM1=1.DO-DM
      M1=DM1
      CAPK=MMDELK(1,DM,IER)
      CAPKP=MMDELK(1,DM1,IER)
C     END
      DO 283 I1=1,ENOPLS
283   ET(I1)=ET(I1)*CAPK/OLDK
      DO 287 I1=1,ZN2M1
287   ZET(I1)=ZET(I1)*CAPKP/OLDKP
C     END


209   CONTINUE


C     DO (TRANSLATE ORIGIN OF INPUT BODY POINTS TO MIDCHORD)

C     PROCEDURE (TRANSLATE ORIGIN OF INPUT BODY POINTS TO MIDCHORD)
      DO 291 L=1,END
291   XBOD(L)=XBOD(L)-RLE/2.-.5*CHORD
C     END


C     DO (TRAILING EDGE FIX OF CAMBER POINTS)

C     PROCEDURE (TRAILING EDGE FIX OF CAMBER POINTS)
      ENOP1=ENO+1
      DO 295 J=ENOP1,ENOPLS
      JNEXT=2*ENO-J
      FAD=1.
      IF(X(ZNO+1,ENO)-X(ZNO-1,ENO).NE.0.)
     1FAD=(X(ZNO,ENO)-X(ZNO-1,ENO))/(X(ZNO+1,ENO)-X(ZNO-1,ENO))
      FAB=1.
      IF(X(2,ENO)-X(ZN2M1-1,ENO).NE.0.)
     1FAB=(X(1,ENO)-X(ZN2M1-1,ENO))/(X(2,ENO)-X(ZN2M1-1,ENO))
      X(ZNO,J)=X(ZNO-1,J)+FAD*(X(ZNO+1,J)-X(ZNO-1,J))
      Y(ZNO,J)=Y(ZNO-1,J)+FAD*(Y(ZNO+1,J)-Y(ZNO-1,J))
      X(1,J)=X(ZN2M1-1,J)+FAB*(X(2,J)-X(ZN2M1-1,J))
      Y(1,J)=Y(ZN2M1-1,J)+FAB*(Y(2,J)-Y(ZN2M1-1,J))
      X(ZN2M1,J)=X(1,J)
295   Y(ZN2M1,J)=Y(1,J)
C     END




C     DO (ADDITION OF BLADE SURFACE ON CLEAN MESH)
      IF(DOSURF)  CALL SURFUP(ET,ZET,XBOD,YBOD,EF)
```

```
7777  FORMAT(14E9.3)
      RETURN
      END
      DOUBLE PRECISION FUNCTION MMDELK(ILPT,ARG,IER)
C-----CALCS COMPLETE ELLIPTIC INTEGRAL OF FIRST KIND FOR MODULUS SQUARED
C      = ARG
      DOUBLE PRECISION ARG,PI,A,B,C,A0,B0
      DATA PI/3.14159265358979300/
      IER = 130
      IF(ILPT.NE.1) STOP 105
      IF(ARG.LT.0.D0.OR.ARG.GE.1.D0) GOTO40
      IER = 0
      A = 1.D0
      B = DSQRT(1.D0 - ARG)
      DO 10 I = 1,15
      C = .5D0 * (A - B)
      IF(DABS(C).LT.1.D-12) GOTO15
      A0 = A
      B0 = B
      A = .5D0 * (A0 + B0)
      B = DSQRT(A0 * B0)
10    CONTINUE
15    IF(I.GT.15) STOP 110
      MMDELK = .5D0 * PI / A
40    RETURN
      END
      SUBROUTINE SURFUP(ET,ZET,XBOD,YBOD,EF)
```

```
C           LOCATES INTERSECTION OF EACH RADIATING LINE IN THE FLATPLATE
C       GRID WITH
C           THE DESIRED BODY SHAPE. ADJUSTS THE SURFACE CONTOURS ('ETA VA
C       LUE STRETCH')
C           SO THAT ALL RADIATING GRID LINES END ON THE BLADE.








C       ET(ENO)=CAPK
C       DELSMX=.06667
C       PIO2=1.57079
C       THETT=THETT*PI/180.
C       THETL=THETL*PI/180.
C       ISA=1
C       PLATE=(CHORD-RLE/2.-RTE/2.)/2.
C       DO (BODY COORDINATE LOADING)
C       ZN2M1=2*ZNO-1
C       NZ2M2=ZN2M1-1
C       DO FOR I=1,NZ2M2
C           ENPOLS=ENOPLS
C           DO (ITERATION SETUP)
C           DO (ITERATION FOR ETA LINE-BODY INTERSECTION)
C           DO FOR J=1,ENOPLS
C               IF(ET(J).GE.ETA) THEN
C               EXIT(J)
C               END
C           END
C           IF(J.EQ.ENOPLS+1) ETA=ET(ENOPLS)
C           IF(RELAXD) THEN
C               XX(I,ENO)=X
C               YY(I,ENO)=Y
C               ETS(I)=ETA
C               DO (ETA VALUE STRETCH)
C           END
C       END
C       DO (EDGE REGIONS)
C       DO FOR J1=2,ENO
C           XX(ZN2M1,J1)=XX(1,J1)
C           YY(ZN2M1,J1)=YY(1,J1)
C       END
C       RETURN
```

```
      DOUBLE PRECISION CAPK,CAPKP
      COMMON/GEOM/ZNO,ENO,RLE,RTE,A,CHORD,XUPS,XDNS,LAMDAO,CC,CAPK
     1,CAPKP,PI
     *,LNK,M1,KM,END,M,DOSURF,AARR,SOL,ENOPLS
     1,SDUM(5),SMOOTH,CHOP,THETT,THETL,TDUM,LEONLY
      COMMON /ENTIRE/XX(100,30),YY(100,30)
      COMMON/SPGENC/DA,DSMAX,RMAX,THIN,DB,TMIN,DSEND
      COMMON/FUNCOS/S,C,D,SN,CN,DN
      COMMON/MAN/DELSMX,PIO2,DELS1,IHUB
      DIMENSION XBOD(200),YBOD(200),SU(400),SD(400),ET(100),ZET(100),
     1NSAVE(25),SEDGT(400),SEDGL(400),
     1ISAVE(25),ETS(100),SYYETA(400),SDXETA(400),SXYETA(400),SDYETA(400)
      INTEGER ZNO,ENO,END,ZN2M1,ENOPLS,ENDM1,ENPOLS,ENDMM1,ENM1
      LOGICAL DUM,RZTRP,IZTRP,THIN,DONE,SMOOTH,DOSURF,LEONLY
      LOGICAL TE,RELAXD,BOTTOM/.FALSE./,FAILD/.FALSE./,EDGES/.FALSE./
      COMPLEX FZTRP,DZTRP,FZ,  Z(400),Z2(400),XOETA(400),YOETA(400)
     1,EDGL(400),EDGT(400),XYETA(400),YYETA(400)
      REAL M,M1,LNK,LAMDAO
      NAMELIST/SPGENS/DA,DSMAX,RMAX,THIN,DB,TMIN,DSEND
      NAMELIST/TESY/I,IS,ETA,Y,X,SPX,SPY,SPE,ITST,DF1DN,DF2DN,DF3DX,
     1F1,F2,F3,DELN,DELX,DELY,FZ,SP
      NAMELIST/TESX/ XYETA,SXYETA,YYETA,SYYETA
      DATA Z/400*(1.E20,0.)/
      DATA Z2/400*(1.E20,0.)/
      DATA EDGT,EDGL,XOETA,YOETA,XYETA,YYETA/2400*(1.E20,0.)/


      ET(ENO)=CAPK
      DELSMX=.06667
      PIO2=1.57079
      THETT=THETT*PI/180.
      THETL=THETL*PI/180.
      ISA=1
      PLATE=(CHORD-RLE/2.-RTE/2.)/2.


C     DO (BODY COORDINATE LOADING)

C     PROCEDURE (BODY COORDINATE LOADING)

      IF(.NOT.SMOOTH) GOTO222
```

```
      IF(LEONLY) GOTO1008                                               QS030730
                                                                        QS030740
      KMH=(KM+1)/2                                                      QS030750
      IF(MOD(KM,2).NE.0)KMH=KMH-1                                       QS030760
      DO 234 I1=1,KMH                                                   QS030770
      I5=I1+KMH                                                         QS030780
234   Z(I1)=CMPLX(XBOD(I5),YBOD(I5))                                    QS030790
      IF(MOD(KM,2).NE.0)                                                QS030800
     1Z(KMH+1)=CMPLX(XBOD(I5+1),YBOD(I5+1))                             QS030810
      IF(MOD(KM,2).NE.0)KMH=KMH+1                                       QS030820
      KWOW=KMH+1+END-KM-2-(KM+1)/2+KM/2                                 QS030830
      KMH1=KMH+1                                                        QS030840
      DO 240 I1=KMH1,KWOW                                               QS030850
      I5=END-I1+KMH                                                     QS030860
240   Z(I1)=CMPLX(XBOD(I5),YBOD(I5))                                    QS030870
      KWOWP1=KWOW+1                                                     QS030880
      ENDMM1=END-1                                                      QS030890
      DO 244 I1=KWOWP1,ENDMM1                                           QS030900
      I5=I1-END+(KM-1)/2+3-MOD(KM,2)                                    QS030910
244   Z(I1)=CMPLX(XBOD(I5),YBOD(I5))                                    QS030920
      GOTO225                                                           QS030930
1008  KMH=END-KM                                                        QS030940
      DO 226 I1=1,KMH                                                   QS030950
      I5=END-I1+1                                                       QS030960
226   Z(I1)=CMPLX(XBOD(I5),YBOD(I5))                                    QS030970
      KWOW=END-1                                                        QS030980
      KMH1=KMH+1                                                        QS030990
      DO 230 I1=KMH1,KWOW                                               QS031000
      I5=I1-KMH+1                                                       QS031010
230   Z(I1)=CMPLX(XBOD(I5),YBOD(I5))                                    QS031020
4447  FORMAT(6E13.5)                                                    QS031030
225   ENDM1=END-1                                                       QS031040
C     WRITE(6,1234) (Z(IW),IW=1,ENDM1),                                 QS031050
C    1(XBOD(IQ),YBOD(IQ),IQ=1,END)                                      QS031060
1234  FORMAT(10E13.6)                                                   QS031070
                                                                        QS031080
                                                                        QS031090
      DA=.17                                                            QS031100
C     WRITE(6,1235)                                                     QS031110
1235  FORMAT(55H0THE FOLLOWING IS A PRINT   OF THE Z MATRIX FROM SURFUP)QS031120
C     WRITE(6,*)Z                                                       QS031130
      CALL XYCALC(1,ENDM1,Z,SU,SD)                                      QS031140
C     WRITE(6,1236)                                                     QS031150
1236  FORMAT(69H0THE FOLLOWING IS A PRINT   OF Z,SU,SD MATRICES AFTER THQS031160
     +E CALL XYCALC)                                                    QS031170
C     WRITE(6,*)Z                                                       QS031180
C     WRITE(6,*)SU                                                      QS031190
C     WRITE(6,*)SD                                                      QS031200
```

```
      END=ENDM1
      ITS=0.
      XTS=0.
      DO 248 I1=1,END
      IF(SU(I1).GT.XTS) ITS=I1
      IF(SU(I1).GT.XTS) XTS=SU(I1)
248   CONTINUE
      KMP=ITS
      ITS=0
      XTS=100.
      DO 254 I1=1,END
      IF(SU(I1).LT.XTS) ITS=I1
      IF(SU(I1).LT.XTS) XTS=SU(I1)
254   CONTINUE
      K1P=ITS
      KM=END-(K1P-KMP)
      KM1=KM+1
      END=END+1
      DO 260 I1=1,KM
      I5=K1P+I1-1
      IF(I5.GE.END-1)I5=I1-END+K1P+1
      XBOD(I1)=SU(I5)
260   YBOD(I1)=SD(I5)
4448  FORMAT(4E13.5,3I7)

C      LOAD SMOOTHED DATA AROUND L.E. REGION INTO EDGL FOR USE IN 'EDGE
C     REGION' TECHNIQUE

      DO 264 I1=KM1,END
      I5=END+KMP-I1
      XBOD(I1)=SU(I5)
264   YBOD(I1)=SD(I5)
      DO 268 I1=KMP,K1P
      IF(SU(I1).LT.-CHOP*.50*PLATE) GOTO271
268   CONTINUE
      I1=K1P
271   I2L=0
      DO 274 I3=I1,END
      IF(ABS(SU(I3)).LT.CHOP*.50*PLATE) GOTO277
      YEE=SU(I3)*SIN(THETL)+SD(I3)*COS(THETL)
      I2L=I2L+1
274   EDGL(I2L)=CMPLX(YEE,SU(I3))
277   NOTO=SGEN(SEDGL,EDGL,I2L)

C      IF (.NOT.LEONLY) LOAD SMOOTHED DATA AROUND T.E. INTO EDGT FOR USE
C      IN 'EDGE REGION'

      IF(LEONLY) GOTO280
```

```
      DO 282 I1=1,KMP
      IF(SU(I1).GT.CHOP*.50*PLATE) GOTO285
282   CONTINUE
285   I2T=0
      DO 288 I3=I1,K1P
      IF(SU(I3).LT.CHOP*.50*PLATE) GOTO291
      YEE=SU(I3)*SIN(THETT)+SD(I3)*COS(THETT)
      I2T=I2T+1
288   EDGT(I2T)=CMPLX(YEE,SU(I3))
291   NOTO=SGEN(SEDGT,EDGT,I2T)



280   DO 298 I1=1,400
      Z(I1)=1.E20
      IF(I1.LE.400) SU(I1)=0.
      IF(I1.LE.400)SD(I1)=0.
298   CONTINUE
222   DO 2100 I1=1,KM
2100  Z(I1)=CMPLX(XBOD(I1),YBOD(I1))
      NOTO= SGEN(SU,Z,KM)
      KM1=KM+1
      IF(NOTO.NE.0) WRITE(6,2) NOTO
2     FORMAT('OSGEN FAILURE',I6)
      KENDO=END-KM
      DO 2104 I1=KM1,END
      I2=I1-KM
2104  Z2(I2)=CMPLX(XBOD(I1),YBOD(I1))
      NOTO=SGEN(SD,Z2,KENDO)
C     END OF BODY COORDINATE LOADING

      ZN2M1=2*ZNO-1
      NZ2M2=ZN2M1-1



      DO 202 I=1,NZ2M2
      ENPOLS=ENOPLS


C     DO (ITERATION SETUP)

C     PROCEDURE (ITERATION SETUP)
      ENPOLS=ENOPLS
      RELAXD=.FALSE.
      FAILD=.FALSE.
      EDGES=.FALSE.
      BOTTOM=.FALSE.
```

```
C     DO (GRID-LINE COORDINATE LOADING)
C     PROCEDURE (GRID-LINE COORDINATE LOADING)
      ITST=0
      JTST=0
      DO 20109 I1=1,400
      XOETA(I1)=1.E20
      YOETA(I1)=1.E20
      IF(I1.LE.400) SDXETA(I1)=0.
      IF(I1.LE.400)SDYETA(I1)=0.
20109 CONTINUE
      DO 20115 I1=1,ENPOLS
      IF(ABS(XX(I,1)).GT.20.)XX(I,1)=SIGN(7.*ABS(XX(I,2)),XX(I,1))
      XOETA(I1)=CMPLX(ET(I1),XX(I,I1))
20115 YOETA(I1)=CMPLX(ET(I1),YY(I,I1))
      NOTO=SGEN(SDYETA,YOETA,ENPOLS)
      IF(NOTO.NE.0) WRITE(6,2) NOTO
      NOTO=SGEN(SDXETA,XOETA,ENPOLS)
      IF(NOTO.NE.0) WRITE(6,2) NOTO
C     END
      Y=YY(I,ENO)
      IF(Y.EQ.0.)Y=SIGN(1.E-04,YY(I,ENO-1))
      X=XX(I,ENO-1)
      XOO=X
      ETA= CAPK*(ENO-2)/(ENO-1)
      IF(Y.LE.0..AND.I.NE.1)BOTTOM=.TRUE.
      IF(I.EQ.ZNO.AND.LAMDAO.GT.0.)BOTTOM=.TRUE.
      DF1DN=(XX(I,ENO)-XX(I,ENO-1))/(ET(ENO-1)-ET(ENO))
      DF2DN=(YY(I,ENO)-YY(I,ENO-1))/(ET(ENO-1)-ET(ENO))
      DF3DX=0.
      IF(DF2DN+DF1DN*DF3DX.EQ.0.)DF3DX=1.
      DELN=0.
      DELX=0.
      DELY=0.
      SP=0.
C     END
C     DO (ITERATION FOR ETA LINE-BODY INTERSECTION)
C     PROCEDURE (ITERATION FOR ETA LINE-BODY INTERSECTION)
      IF(ABS(XX(I,ENO)).GT.CHOP*PLATE.AND.
     1((.NOT.LEONLY.OR.I.LE.ZNO/2.OR.I.GE.3*ZNO/2))) GOTO2119
C     DO UNTIL(RELAXD.OR.FAILD)
2122  ITST=ITST+1
      X=X+DELX
```

```
      Y=Y+DELY
      SPY=0.
      SPX=0.
      SP=0.
      SPE=0.
      ETA=ETA+DELN
      IF(ETA.LT.0.)ETA=ET(2)
      IF(ETA.GT.2.*CAPK)ETA=ET(ENOPLS)
      IF(.NOT.EDGES) GOTO2124
      IF(ETA.GT..90*CAPK.AND.ITST.GT.20)ETA=.90*CAPK
      DUM=RZTRP(SXYETA,XYETA,ETA,I2S,SPX)
      GETA=AIMAG(FZTRP(SXYETA,XYETA,SPX,I2S))
      DUM=RZTRP(SYYETA,YYETA,ETA,I2Y,SPY)
      FETA=AIMAG(FZTRP(SYYETA,YYETA,SPY,I2Y))
      GOTO2125
2124  DUM=RZTRP(SDXETA,XOETA,ETA,ENPOLS,SPX)
      GETA=AIMAG(FZTRP(SDXETA,XOETA,SPX,ENPOLS))
      DUM=RZTRP(SDYETA,YOETA,ETA,ENPOLS,SPY)
      FETA=AIMAG(FZTRP(SDYETA,YOETA,SPY,ENPOLS))
2125  F1=X-GETA
      F2=Y-FETA
      IF(.NOT.BOTTOM) GOTO2126
      DUM=RZTRP(SD,Z2,X,KENDO,SP)
      FX=AIMAG(FZTRP(SD,Z2,SP,KENDO))
      GOTO2127
2126  DUM=RZTRP(SU,Z,X,KM,SP)
      FX=AIMAG(FZTRP(SU,Z,SP,KM))
2127  F3 = Y-FX
      RELAXD=(ABS(F1)+ABS(F2)+ABS(F3)).LT..0001
C      IF FIRST TRY IS UNSUCCESSFUL, GET SMOOTHED SLOPE DATA AND TRY AGA
C     IN
      IF((ITST.LE.20.AND.ABS(DELN/ETA).LE.1000.).OR.EDGES) GOTO2128
C     DO (ITERATION WITH BETTER SLOPES)
C     PROCEDURE(ITERATION WITH BETTER SLOPES)
      WRITE(6,5) I
5     FORMAT('OITERATION PROCEEDS WITH SMOOTHER SLOPE DATA FOR LINE ',I4
     1)
      DO 2139 I1=1,400
      XYETA(I1)=1.E20
      YYETA(I1)=1.E20
      IF(I1.LE.400) SXYETA(I1)=0.
      IF(I1.LE.400)SYYETA(I1)=0.
2139  CONTINUE
C     DO (ITERATION SETUP AGAIN)
```

```
C       PROCEDURE (ITERATION SETUP)
        ENPOLS=ENOPLS
        RELAXD=.FALSE.
        FAILD=.FALSE.
        EDGES=.FALSE.
        BOTTOM=.FALSE.

C       DO (GRID-LINE COORDINATE LOADING AGAIN)
C       PROCEDURE (GRID-LINE COORDINATE LOADING)
        ITST=0
        JTST=0
        DO 2109 I1=1,400
        XOETA(I1)=1.E20
        YOETA(I1)=1.E20
        IF(I1.LE.400) SDXETA(I1)=0.
        IF(I1 .LE.400)SDYETA(I1)=0.
2109    CONTINUE
        DO 21115 I1=1,ENPOLS
        IF(ABS(XX(I,1)).GT.20.)XX(I,1)=SIGN(7.*ABS(XX(I,2)),XX(I,1))
        XOETA(I1)=CMPLX(ET(I1),XX(I,I1))
21115   YOETA(I1)=CMPLX(ET(I1),YY(I,I1))
        NOTO=SGEN(SDYETA,YOETA,ENPOLS)
        IF(NOTO.NE.0) WRITE(6,2) NOTO
        NOTO=SGEN(SDXETA,XOETA,ENPOLS)
        IF(NOTO.NE.0) WRITE(6,2) NOTO
C       END

        Y=YY(I,ENO)
        IF(Y.EQ.0.)Y=SIGN(1.E-04,YY(I,ENO-1))
        X=XX(I,ENO-1)
        XOO=X
        ETA= CAPK*(ENO-2)/(ENO-1)
        IF(Y.LE.0..AND.I.NE.1)BOTTOM=.TRUE.
        IF(I.EQ.ZNO.AND.LAMDAO.GT.0.)BOTTOM=.TRUE.
        DF1DN=(XX(I,ENO)-XX(I,ENO-1))/(ET(ENO-1)-ET(ENO))
        DF2DN=(YY(I,ENO)-YY(I,ENO-1))/(ET(ENO-1)-ET(ENO))
        DF3DX=0.
        IF(DF2DN+DF1DN*DF3DX.EQ.0.)DF3DX=1.
        DELN=0.
        DELX=0.
        DELY=0.
        SP=0.
C       END

        EDGES=.TRUE.
        DO 2146 I6=1,ENO
C       DO 2146 I6=1,ENOPLS
        XYETA(I6)=XOETA(I6)
```

```
2146  YYETA(I6)=YOETA(I6)
      DA=.02
      DELSMX=.06667
C     I2S=ENOPLS
C      SMOOTH THE SLOPE DATA
      CALL XYCALC(1,I2S,XYETA,SXYETA,SYYETA)
      DO 2150 I6=1,I2S
2150  XYETA(I6)=CMPLX(SXYETA(I6),SYYETA(I6))
      DO 2154 I4=1,400
      SXYETA(I4)=0.
2154  SYYETA(I4)=0.
C     I2Y=ENOPLS
      CALL XYCALC(1,I2Y,YYETA,SXYETA,SYYETA)
      DELSMX=.066667
      DO 2158 I6=1,I2Y
2158  YYETA(I6)=CMPLX(SXYETA(I6),SYYETA(I6))
      NOTO=SGEN(SXYETA,XYETA,I2S)
      NOTO=SGEN(SYYETA,YYETA,I2Y)
C     WRITE(6,TESX)
C      END OF BETTER SLOPE ACQUISITION, EDGES NOW = .TRUE.
2128  IF(ITST.GT.50.OR.ABS(DELN/ETA).GT.1000.) FAILD=.TRUE.
      IF(RELAXD) GOTO2129
      DELN = (F3-F2-DF3DX*F1)/(DF2DN+DF1DN*DF3DX)
      DELX=-F1-DF1DN*DELN
      DELY = -F3 -DF3DX*DELX
C     DO (SEARCH FOR BODY SLOPE)
C     PROCEDURE (SEARCH FOR BODY SLOPE)
      K4=1
      K3=KM
      K2=1
      IF(.NOT.BOTTOM) GOTO2162
      K2=KM+1
      K3=END
      K4=1
2162  DO 2164 K1=K2,K3,K4
      IF(XBOD(K1).GE. X+DELX) GOTO2167
2164  CONTINUE
      K1=K3
2167  DF3DX=(YBOD(K1-1)-YBOD(K1))/
     * (XBOD(K1)-XBOD(K1-1))
C     END

C     DO (SEARCH FOR GRID-LINE SLOPE)
C     PROCEDURE (SEARCH FOR GRID-LINE SLOPE)
      IF(.NOT.EDGES) GOTO2170
      DO 2172 J=1,I2S
      IF(REAL(XYETA(J)).GE.ETA) GOTO2175
2172  CONTINUE
```

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2175  IF(J.EQ.I2S+1) J=I2S                                               QS034090
      DO 2180 JY=1,I2Y                                                  QS034100
      IF(REAL(YYETA(JY)).GE.ETA) GOTO2183                               QS034110
2180  CONTINUE                                                          QS034120
2183  IF(JY.EQ.I2Y+1) JY=I2Y                                            QS034130
      DF1DN=(AIMAG(XYETA(J))-AIMAG(XYETA(J-1)))/                        QS034140
     1(REAL(XYETA(J-1))-REAL(XYETA(J)))                                 QS034150
      DF2DN=(AIMAG(YYETA(JY))-AIMAG(YYETA(JY-1)))/                      QS034160
     1(REAL(YYETA(JY-1))-REAL(YYETA(JY)))                               QS034170
      GOTO2171                                                          QS034180
2170  DO 2188 J=1,ENOPLS                                                QS034190
      IF(ET(J).GE.ETA) GOTO2191                                         QS034200
2188  CONTINUE                                                          QS034210
2191  IF(J.EQ.ENOPLS+1) J=ENOPLS                                        QS034220
      DF1DN=(XX(I,J)-XX(I,J-1))/(ET(J-1)-ET(J))                         QS034230
      DF2DN=(YY(I,J)-YY(I,J-1))/(ET(J-1)-ET(J))                         QS034240
2171  CONTINUE                                                          QS034250
C     END                                                               QS034260
                                                                        QS034270
2129  IF(.NOT.(DF2DN+DF3DX.EQ.0..OR.                                    QS034280
     1((I.EQ.1.OR.I.EQ.ZNO).AND.LAMDAO.EQ.0.).OR.                       QS034290
     1(.NOT.SMOOTH.AND.ABS(XX(I,ENO)).GT..98*PLATE.AND.FAILD))) GOTO2121QS034300
      RELAXD=.TRUE.                                                     QS034310
      FAILD=.FALSE.                                                     QS034320
      Y=YY(I,ENO)                                                       QS034330
      X=XBOD(KM)                                                        QS034340
      IF(I.EQ.1)X=XBOD(1)                                               QS034350
      IF(SMOOTH) GOTO2135                                               QS034360
      Y=0.                                                              QS034370
      X=XBOD(1)                                                         QS034380
      IF(I.GT.ZNO/2.AND.I.LT.3*ZNO/2)X=XBOD(KM)                         QS034390
2135  DUM=IZTRP(SDXETA,XOETA,X,ENO,SPE)                                 QS034400
      ETA=REAL(FZTRP(SDXETA,XOETA,SPE,ENO))                             QS034410
                                                                        QS034420
2121  IF(.NOT.(RELAXD.OR.FAILD))GOTO2122                                QS034430
C     END OF ITERATION FOR ETA LINE-BODY INTERSECTION                   QS034440
2119  IF(RELAXD.OR.ABS(XX(I,ENO)).LE.CHOP*PLATE.AND..NOT.FAILD) GOTO3004QS034450
      IF(FAILD)WRITE(6,3) I                                             QS034460
      IF(.NOT.FAILD)WRITE(6,4) I,XX(I,ENO),PLATE                        QS034470
3     FORMAT('OITERATION FAILD FOR LINE ',I4,                           QS034480
     1' PROCEEDING TO EDGE REGION TECHNIQUE')                           QS034490
4     FORMAT('OITERATION NOT ATTEMPTED FOR LINE ',I4,                   QS034500
     1', BODY X TOO CLOSE TO LE OR TE: ',2E15.6,'PROCEED TO EDGE TECH.')QS034510
      ISAVE(ISA)=I                                                      QS034520
      NSAVE(ISA)=1                                                      QS034530
      IF(BOTTOM)NSAVE(ISA)=-1                                           QS034540
      ISA=ISA+1                                                         QS034550
3004  DO 208 J=1,ENOPLS                                                 QS034560
```

```
      IF(ET(J).GE.ETA) GOTO211
208   CONTINUE
211   IF(J.EQ.ENOPLS+1) ETA=ET(ENOPLS)
      IF(.NOT.RELAXD) GOTO202
      XX(I,ENO)=X
      YY(I,ENO)=Y
      ETS(I)=ETA
C     DO (ETA VALUE STRETCH)
C     PROCEDURE (ETA VALUE STRETCH)
      ENM1=ENO-1
      DO 20196 J=2,ENM1
      ETANEW=ET(J)/CAPK*ETA
      SPX=SDXETA(1)
      SPY=SDYETA(1)
      DUM=RZTRP(SDXETA,XOETA,ETANEW,ENPOLS,SPX)
      XX(I,J)=AIMAG(FZTRP(SDXETA,XOETA,SPX,ENPOLS))
      DUM=RZTRP(SDYETA,YOETA,ETANEW,ENPOLS,SPY)
20196 YY(I,J)=AIMAG(FZTRP(SDYETA,YOETA,SPY,ENPOLS))
C     END


202   CONTINUE
C     DO (EDGE REGIONS)
C     PROCEDURE (EDGE REGIONS)
C
C 'EDGE REGION TECHNIQUE' = INTERPOLATE ON CURVE OF INTERSECTION POINTS
C                           DEFINED BY SUCCESSFUL NEIGHBORING LINES.
C
      NOZO2=ZNO/2
      IF(ISAVE(1).GE.NOZO2) GOTO2020
      DO 2202 I3=1,ISA
      IF(ISAVE(I3).GT.NOZO2) GOTO2205
2202  CONTINUE
      I3=ISA
2205  I3=I3-1
      ISAP=ISA
      DO 2208 I4=1,I3
      ISAVE(ISAP)=ISAVE(I4)
2208  ISAP=ISAP+1
      ISAM1=ISA-1
      DO 2212 I4=1,ISAM1
      I4I3=I4+I3
2212  ISAVE(I4)=ISAVE(I4I3)
2020  DO 2216 I1=1,400
      XYETA(I1)=1.E20
      YYETA(I1)=1.E20
      IF(I1.GT.400) GOTO2216
      SXYETA(I1)=0.
```

```
      SYYETA(I1)=0.
      SU(I1)=0.
      SD(I1)=0.
 2216 CONTINUE
      I2=0
      IS=1
      NZ2M11=ZN2M1-1

C      LOAD VALUES OF BODY Y AND ZET FROM  ALL SUCCESSFUL LINE ITERATION
C     S INTO
C      THE ARRAY XYETA AND SMOOTH IT.
      DO 2222 I1=NOZO2,NZ2M11
      IF(IS.GT.ISA) GOTO2222
      IF(ISAVE(IS).EQ.I1) GOTO2228
      I2=I2+1
      THE=XX(I1,ENO)*(THETL-THETT)/(-1.6*CHOP*PLATE)
      IF(XX(I1,ENO).LT.-CHOP*.80*PLATE)THE=THETL
      IF(XX(I1,ENO).GT.CHOP*.80*PLATE)THE=THETT
      YEE=YY(I1,ENO)*COS(THE)+XX(I1,ENO)*SIN(THE)
      YEE=YEE*10.
      XYETA(I2)=CMPLX(ZET(I1),YEE)
      YYETA(I2)=CMPLX(ZET(I1),ETS(I1))
 2228 IF(ISAVE(IS).EQ.I1)IS=IS+1
 2222 CONTINUE
      DO 2230 I1=1,NOZO2
      IF(ISAVE(IS).EQ.I1) GOTO2234
      I2=I2+1
      ZED=ZET(I1)-2.*CAPKP
      THE=XX(I1,ENO)*(THETL-THETT)/(-1.6*PLATE)
      IF(XX(I1,ENO).LT.-CHOP*.80*PLATE)THE=THETL
      IF(XX(I1,ENO).GT.CHOP*.80*PLATE)THE=THETT
      YEE=YY(I1,ENO)*COS(THE)+XX(I1,ENO)*SIN(THE)
      YEE=YEE*10.
      XYETA(I2)=CMPLX(ZED,YEE)
      YYETA(I2)=CMPLX(ZED,ETS(I1))
 2234 IF(ISAVE(IS).EQ.I1)IS=IS+1
 2230 CONTINUE
      I2S=I2
      DELSMX=.5
      DA=.05
      CALL XYCALC(1,I2S,XYETA,SU,SD)
      DELSMX=.066667
      DO 2236 I6=1,I2S
 2236 XYETA(I6)=CMPLX(SU(I6),SD(I6))
      NOTO=SGEN(SXYETA,XYETA,I2S)
      NOTO=SGEN(SYYETA,YYETA,I2)
C     WRITE(6,TESX)
      SPT=0.
```

```
      SPL=0.
      ISAM1=ISA-1
      DO 2240 IS=1,ISAM1
      SPX=0.
      SPE=0.
      TE=.FALSE.
      I1=ISAVE(IS)
      I=I1
      IMM1=I-1
      IF(IMM1.EQ.0)IMM1=ZN2M1-1


      IF(I.GT.ZN2M1/4.AND.I.LT.3*ZN2M1/4)TE=.TRUE.


      IF(TE)SPL=0.
      ZED=ZET(I1)

C      INTERPOLATE ON THE TABLE OF Y VALUES IN XYETA USING THE KNOWN VAL
C     UE OF ZETA
C      FOR EACH UNSUCCESSFUL LINE.

      IF(.NOT.TE.AND.ZED.GT..85*CAPKP)ZED=ZED-2.*CAPKP
      DUM=RZTRP(SXYETA,XYETA,ZED,I2S,SPX)
      Y=AIMAG(FZTRP(SXYETA,XYETA,SPX,I2S))/10.


C      AFTER Y IS FOUND, OBTAIN X FROM TABLE OF L.E. AND T.E. BODY SHAPE
C     S
C      IN EDGL AND EDGT.


      IF(.NOT.SMOOTH) GOTO2244
      IF(.NOT.TE) GOTO2246
      DUM=RZTRP(SEDGT,EDGT,Y,I2T,SPT)
      X=AIMAG(FZTRP(SEDGT,EDGT,SPT,I2T))
      IF(ABS(X-XX(IMM1,ENO)).LE.1.5/FLOAT(ZNO)) GOTO22461
      DUM=RZTRP(SEDGT,EDGT,Y,I2T,SPT)
      X=AIMAG(FZTRP(SEDGT,EDGT,SPT,I2T))
22461 GOTO2245
2246  DUM=RZTRP(SEDGL,EDGL,Y,I2L,SPL)
      X=AIMAG(FZTRP(SEDGL,EDGL,SPL,I2L))
      IF(ABS(X-XX(IMM1,ENO)).LE.1.5/FLOAT(ZNO)) GOTO22441
      DUM=RZTRP(SEDGL,EDGL,Y,I2L,SPL)
      X=AIMAG(FZTRP(SEDGL,EDGL,SPL,I2L))
22441 GOTO2245
2244  IF(Y.GT.0..OR.I.EQ.1) GOTO2252
      DUM=IZTRP(SD,Z2,Y,KENDO,SP)
```

```
      X=REAL(FZTRP(SD,Z2,SP,KENDO))
      GOTO2245
2252  DUM=IZTRP(SU,Z,Y,KM,SP)
      X=REAL(FZTRP(SU,Z,SP,KM))


2245  IF(.NOT.TE)Y=(Y-X*SIN(THETL))/COS(THETL)
      IF(TE)Y=(Y-X*SIN(THETT))/COS(THETT)
C     DO (GRID-LINE COORDINATE LOADING)
C     PROCEDURE (GRID-LINE COORDINATE LOADING)
      ITST=0
      JTST=0
      DO 21109 I1=1,400
      XOETA(I1)=1.E20
      YOETA(I1)=1.E20
      IF(I1.LE.400) SDXETA(I1)=0.
      IF(I1.LE.400)SDYETA(I1)=0.
21109 CONTINUE
      DO 2115 I1=1,ENPOLS
      IF(ABS(XX(I,1)).GT.20.)XX(I,1)=SIGN(7.*ABS(XX(I,2)),XX(I,1))
      XOETA(I1)=CMPLX(ET(I1),XX(I,I1))
2115  YOETA(I1)=CMPLX(ET(I1),YY(I,I1))
      NOTO=SGEN(SDYETA,YOETA,ENPOLS)
      IF(NOTO.NE.0) WRITE(6,2) NOTO
      NOTO=SGEN(SDXETA,XOETA,ENPOLS)
      IF(NOTO.NE.0) WRITE(6,2) NOTO
C     END
      DUM=IZTRP(SDXETA,XOETA,X,ENPOLS,SPE)
      ETA=REAL(FZTRP(SDXETA,XOETA,SPE,ENPOLS))


C     DO (ETA VALUE STRETCH FOR EDGE REGION POINTS)

C     PROCEDURE (ETA VALUE STRETCH)
      ENM1=ENO-1
      DO 2196 J=2,ENM1
      ETANEW=ET(J)/CAPK*ETA
      SPX=0.
      SPY=0.
      DUM=RZTRP(SDXETA,XOETA,ETANEW,ENPOLS,SPX)
      XX(I,J)=AIMAG(FZTRP(SDXETA,XOETA,SPX,ENPOLS))
      DUM=RZTRP(SDYETA,YOETA,ETANEW,ENPOLS,SPY)
2196  YY(I,J)=AIMAG(FZTRP(SDYETA,YOETA,SPY,ENPOLS))
C     END
      IF(XX(I,1).EQ.XX(I,ENO-1).AND.YY(I,1).EQ.YY(I,ENO-1)) WRITE (6,7)I
7     FORMAT('OGRID LINE NO. ',I4,' HAS DEGENERATED TO POINT.',
     1' TRY THETL,THETT = LE,TE CAMBER ANGLES')
      XX(I,ENO)=X
```

```
 2240 YY(I,END)=Y
C     END
      DO 218 J1=2,END
      XX(ZN2M1,J1)=XX(1,J1)
  218 YY(ZN2M1,J1)=YY(1,J1)
      RETURN


      END
      SUBROUTINE TOSTAG(S,ZET,CHORDO)
C
C     INVERT THE CONFORMAL TRANSFORMATION FROM FLATPLATE CASCADE OF ZER
CO STAGGER
C     TO THE UNIT CIRCLE. ADD DESIRED SOLIDITY AND STAGGER TERMS AND RE
CVERT TO
C     PHYSICAL PLANE.
C
C     SOURCE,      HAWTHORNE (LISTED AS REF. 4 OF REF. 2 OF THE USERS M
CANUAL)

      INTEGER ZNO,ZN2M1,ENO,ENOPLS
      DIMENSION ZET(100)
      COMMON/GEOM/ZNO,ENO,RLE,RTE,A,CHORD,XUPS,XDNS,STAG,F,CAKK(4),PI,
     1LNK,VB,KN,NED,BB,DOSURF,R,SOLID2,ENOPLS
      COMMON /ENTIRE/ XGRID(100,30),YGRID(100,30)
      COMPLEX AI/(0.,1.)/,AHTAN,AHTAN2,AHYPT,ZCMX,WCMX,AQT1,AQT2,READK
      COMPLEX ZGRID
      READK=1./R
      ALAMDA=.5*(READK+1./READK)
      ZN2M1=2*ZNO-1
      N2ZM11=ZN2M1-1
      XGRID(1,1)=4.*XGRID(2,1)
      XGRID(ZN2M1,1)=XGRID(1,1)
      XGRID(ZNO,1)=-XGRID(1,1)
      DO 1 I=1,N2ZM11
      DO 1 J=1,ENOPLS
      SIG=1.
      IF(J.GT.ENO) SIG=-1.
```

```
      ZGRID=(XGRID(I,J)+AI*YGRID(I,J)*SIG)                              QS036970
      AHTAN=CEXP((ZGRID        )/2.)-CEXP(-(ZGRID        )/2.)          QS036980
      AHTAN2=CEXP((ZGRID        )/2.)+CEXP(-(ZGRID        )/2.)         QS036990
      AHYPT=AHTAN/AHTAN2                                                QS037000
      ZCMX= ALAMDA*AHYPT                                                QS037010
      WCMX=ZCMX+CSQRT(ZCMX-1.)*CSQRT(ZCMX+1.)                           QS037020
      IF(R.LT.1.1.AND.YGRID(I,J).EQ.0.)WCMX=CMPLX(REAL(WCMX),0.)        QS037030
      IF(ABS(ABS(REAL(WCMX))-R).LT.1.E-07)                              QS037040
     1AQT1=CMPLX(SIGN(25.,XGRID(I,J)),0.)                               QS037050
      IF(ABS(ABS(REAL(WCMX))-R).GE.1.E-07)                              QS037060
     1AQT1=(CLOG(READK*WCMX+1.)-CLOG(READK*WCMX-1.))                    QS037070
      IF(ZET(I) .LT.0.)AQT1=AQT1-2.*AI*PI                               QS037080
                                                                        QS037090
C      ADD STAGGER TERM                                                 QS037100
                                                                        QS037110
      AQT1=AQT1*CEXP(-AI*STAG)                                          QS037120
      AQT2=(CLOG(WCMX+READK)-CLOG(WCMX-READK))*CEXP(AI*STAG)            QS037130
                                                                        QS037140
C      CORRECT FOR PROPER SOLIDITY COEFFICIENT AND ASSEMBLE X+IY        QS037150
      ZCMX=(AQT1+AQT2)/(2.*PI*SOLID2)*CHORD                             QS037160
      XGRID(I,J)= REAL(ZCMX)+SIN(STAG)/2./SOLID2 *CHORD                 QS037170
      YGRID(I,J)= SIG*(AIMAG(ZCMX)+COS(STAG)/2./SOLID2 *CHORD)          QS037180
      YGRID(ZN2M1,J)=YGRID(1,J)                                         QS037190
    1 XGRID(ZN2M1,J)=XGRID(1,J)                                         QS037200
      RETURN                                                            QS037210
      END                                                               QS037220
      SUBROUTINE ALTERP(COVERS,STAG,ALFA,R)                             QS037230
                                                                        QS037240
C      PERFORMS DOUBLE LINEAR INTERPOLATION ON STAGGER ANGLE AND SOLIDITQS037250
C     Y TO OBTAIN                                                       QS037260
C      POSITIONS OF VORTEX SINGULARITIES IN THE CONFORMAL PLANE.        QS037270
                                                                        QS037280
C      SOURCE, HAWTHORNE (LISTED AS REF. 4 OF REF. 2. OF USERS MANUAL)  QS037290
                                                                        QS037300
                                                                        QS037310
                                                                        QS037320
      DIMENSION CSTAB(25,25),GAMTAB(25),RTAB(25),ISTAR(2)               QS037330
                                                                        QS037340
C      TABULATED VALUES FROM THE RANGE OF FIGS B,5C AND B,5D (PP.30,31) QS037350
C     OF HAWTHORNE                                                      QS037360
      DATA RTAB,GAMTAB/1.001,                                           QS037370
     1                1.005,1.01,1.02,1.03,1.04,1.05,1.1,1.2,1.3,1.4QS037380
     1,1.5,1.6,1.7,1.8,1.9,2.,2.25,2.5,2.75,3.,3.5,4.,4.5,5.,0.,5.,10., QS037390
     115.,20.,25.,30.,35.,40.,45.,50.,55.,60.,65.,70.,75.,80.,85.,91.,  QS037400
     195.,100.,4*150./                                                  QS037410
      PI=3.14159265                                                     QS037420
      DO 1 J=1,19                                                       QS037430
      G=GAMTAB(J)*PI/180.                                               QS037440
```

```
      DO 1 I=1,25
      RD=RTAB(I)

C     EQNS. FROM FIGS B,5C AND D

      AL=ATAN(TAN(G)*(RD*RD-1.)/(RD*RD+1.))
1     CSTAB(I,J)=1./PI*(COS(G)*ALOG((RD*RD+2.*RD*COS(AL)+1.)/(RD*RD-2.
     1*RD*COS(AL)+1.))+2.*SIN( G)*ATAN(2.*RD*SIN(AL)/(RD*RD-1.)))


      STAGG=STAG*180./PI
      DO 20 J=1,25
      IF(STAGG.LE.GAMTAB(J))GOTO21
20    CONTINUE
      J=25
21    JSTAR=J
      JSM1=J-1
      DO 40 J=JSM1,JSTAR
      J1=J-JSM1+1
      DO 30 I=1,25
      IF(COVERS.GE.CSTAB(I,J))GOTO31
30    CONTINUE
      I=25
31    ISTAR(J1)=I
40    CONTINUE
      ISM1=ISTAR(2)-1
      ISSM1=ISTAR(1)-1
      IS=ISTAR(2)
      ISS=ISTAR(1)
      R1=RTAB(ISS)+(RTAB(ISSM1)-RTAB(ISS))*(COVERS-CSTAB(ISS,JSM1))/
     1(CSTAB(ISSM1,JSM1)-CSTAB(ISS,JSM1))
      R2=RTAB(IS)+(RTAB(ISM1)-RTAB(IS))*(COVERS -CSTAB(IS,JSTAR))/
     1(CSTAB(ISM1,JSTAR)-CSTAB(IS,JSTAR))
      R=R1+(R2-R1)*(STAGG-GAMTAB(JSM1))/(GAMTAB(JSTAR)-GAMTAB(JSM1))
      IF(COVERS.GT.5.)R=1.0001
      ALFA=ATAN(TAN(STAG)*(R*R-1.)/(R*R+1.))
      RETURN
      END
      FUNCTION FUDS(E,Z,SCK)

C     CALCULATES FUNCTION 'T' IN EQN. 1., REF. 2. OF USER MANUAL

      COMMON/GEOM/ DUMP(19),G
      COMMON/FUNCOS/S,C,D,SN,CN,DN
      CALL JELF(S,C,D,E,SCK)
      CALL JELF(SN,CN,DN,Z,G)
      B=S*DN*S*DN+(C*D*SN*CN)**2
```

```
      FUDS = SQRT(B)
      RETURN
      END
      FUNCTION OWOW(SCK)

C      CALCULATES FUNCTION 'OMEGA' IN EQN. 1., REF. 2 OF USERS MANUAL


      COMMON/FUNCOS/S,C,D,SN,CN,DN
      IF(S.EQ.0.)S=1.E-20
      B= C*D*SN*CN/S/DN
      OWOW = ATAN(B)
      RETURN
      END
      FUNCTION BADZAC(SCK)

C      CALCULATES FUNCTIUON 'GAMMA' IN EQN. 1., REF. 2 OF USERS MANUAL


      COMMON/FUNCOS/S,C,D,SN,CN,DN
      BADZAC = CN*CN+(1.-SCK)*S*S*SN*SN
      RETURN
      END
      SUBROUTINE JELF(SN,CN,DN,X,SCK)

C      COMPUTES JACOBIAN ELLIPTIC FCNS SN,CN,DN

C      IF X IS GIVEN AS THE ELLIPTIC INTEGRAL OF THE FIRST KIND WITH MOD
C     ULUS K
C      FROM ZERO TO SIN(PHI)  WITH  0<PHI<PI/2, THEN
C               SCK = 1-K*K
C               SN(X,K)=SIN(PHI)
C               CN(X,K)=COS(PHI)
C    AND        DN(X,K)=SQRT(1.-K*K*SIN(PHI)**2)



      DIMENSION ARI(12),GEO(12)
      CM=SCK
      Y=X
      IF(SCK) 3,1,4
1     D=EXP(X)
      A=1./D
      B=A+D
      CN=2./B
      DN=CN
      SN=TANH(X)
2     RETURN
```

```
3       D=1.-SCK                                                        QS038410
        CM=-SCK/D                                                       QS038420
        D=SQRT(D)                                                       QS038430
        Y=D*X                                                           QS038440
4       A=1.                                                            QS038450
        DN=1.                                                           QS038460
        DO 6 I=1,12                                                     QS038470
        L=I                                                             QS038480
        ARI(I)=A                                                        QS038490
        CM=SQRT(CM)                                                     QS038500
        GEO(I)=CM                                                       QS038510
        C=(A+CM)*.5                                                     QS038520
        IF(ABS(A-CM)-1.E-4*A)7,7,5                                      QS038530
5       CM=A*CM                                                         QS038540
6       A=C                                                             QS038550
7       Y=C*Y                                                           QS038560
        SN=SIN(Y)                                                       QS038570
        CN=COS(Y)                                                       QS038580
        IF(SN)8,13,8                                                    QS038590
8       A=CN/SN                                                         QS038600
        C=A*C                                                           QS038610
        DO 9 I=1,L                                                      QS038620
        K=L-I+1                                                         QS038630
        B=ARI(K)                                                        QS038640
        A=C*A                                                           QS038650
        C=DN*C                                                          QS038660
        DN=(GEO(K)+A)/(B+A)                                             QS038670
9       A=C/B                                                           QS038680
        A=1./SQRT(C*C+1.)                                               QS038690
        IF(SN)10,11,11                                                  QS038700
10      SN=-A                                                           QS038710
        GOTO 12                                                         QS038720
11      SN=A                                                            QS038730
12      CN=C*SN                                                         QS038740
13      IF(SCK)14,2,2                                                   QS038750
14      A=DN                                                            QS038760
        DN=CN                                                           QS038770
        CN=A                                                            QS038780
        SN=SN/D                                                         QS038790
        RETURN                                                          QS038800
        END                                                             QS038810
        SUBROUTINE XYCALC(KSTART,K2,Z,X,Y)                              QS038820
C              -- XYCALC --                                             QS038830
C.....GENERATES DATA FILES FOR ON-BODY POINTS.                          QS038840
                                                                        QS038850
        INTEGER SGEN                                                    QS038860
        REAL                             C(400),S(400),SP(400)          QS038870
        COMPLEX Z(400),DZ(400),D2Z,ZZ,FZTRP,DZTRP                       QS038880
```

```
      LOGICAL THIN,EVEN,SPGEN,DONE
      COMMON /MAN/ DELSMX,PIO2,DELS1,IHUB
      DIMENSION X(400),Y(400)
      COMMON /SPGENC/     A,DSMAX,RMAX,THIN,B,TMIN,DSEND
      DATA NSMAX,EMPTY/400,1.0E20/

C.....INITIALIZE PROGRAM.
      S1=0.0
      NMAX=400
      DSMAX=DELSMX
      DELS1=DELSMX
      THIN=.FALSE.
      RMAX=1.2
      DSEND=DSMAX
      DONE=.FALSE.
      EVEN=.FALSE.
      B=0.3
      TMIN=0.1
      NFIN=0
      NSP=0

C.....INPUT BODY POINTS AND BODY TYPE.
      DO 25 I=1,NSMAX
      IF (REAL(Z(I)).EQ.EMPTY) GO TO 30
25    NS=I
30    S(1)=S1
      IBAD=SGEN(S,Z,NS)
C     WRITE(6,140)
140   FORMAT(31H0THE FOLLOWING IS S FROM XYCALC///)
C     WRITE(6,*)S
C     WRITE(6,145)
145   FORMAT(31H0THE FOLLOWING IS Z FROM XYCALC///)
C     WRITE(6,*)Z
C     WRITE(6,150)
150   FORMAT(32H0THE FOLLOWING IS NS FROM XYCALC///)
C     WRITE(6,*)NS
      IF (IBAD.NE.0) WRITE (6,125)IBAD

C.....SET UP DERIVATIVES + CURVATURES.
      DO 35 I=1,NS
35    DZ(I)=DZTRP(S,Z,S(I),NS)
      DO 40 I=1,NS
      D2Z=DZTRP(S,DZ,S(I),NS)
40    C(I)=AIMAG(CONJG(DZ(I))*D2Z)/CABS(DZ(I))**3

C.....INPUT AUXILLIARY (CONTROL) DATA.
      IF (NFIN.EQ.0) NFIN=NS
      SFIN=S(NFIN)
```

```
      DSMAX=AMAX1(DSMAX,DSEND)

C.....GENERATE BODY POINTS ON A SEGMENT.
      IF (.NOT.SPGEN(S,Z,C,NS,SP,NSP,SFIN,NMAX)) GO TO 130


C.....OUTPUT RESULTING ON-BODY POINTS.
85    DO 90 I=1,NSP
      IBY=KSTART+I-1
      ZZ=FZTRP(S,Z,SP(I),NS)
C     DZ(I)=DZTRP(S,Z,SP(I),NS)
C     D2Z=DZTRP(S,DZ,SP(I),NS)
C     C(I)= AIMAG(CONJG(DZ(I))*D2Z)/CABS(DZ(I))**3
      X(IBY)=REAL(ZZ)
90    Y(IBY)=AIMAG(ZZ)
      K1=KSTART
      K2=NSP+KSTART-1
120   RETURN
C.....ERROR MESSAGES.
125   FORMAT(21H SGEN FAILED.  IBAD= ,I3)
130   WRITE (6,135)
135   FORMAT(34H SPGEN UNABLE TO COMPLETE SEGMENT )
      STOP
      END
      INTEGER FUNCTION SGEN(S,F,NS)
      REAL S(400)
      COMPLEX F(400),DZTRP
      DATA MAX,N,FN,TEST/4,10,10.0,0.01/
      DO 10 I=2,NS
10    S(I)=S(I-1)+CABS(F(I)-F(I-1))
      DO 30 K=1,MAX
      SGEN=0
      DO 25 I=2,NS
      DS=S(I)-S(I-1)
      DARG=DS/FN
      ARGO=S(I-1)-DARG/2.0
      SUM=0.0
      DO 15 J=1,N
      ARG=ARGO+FLOAT(J)*DARG
      TVQQ=CABS(DZTRP(S,F,ARG,NS))-1.0
15    SUM=SUM+TVQQ
      SUM=SUM/FN
      ERROR=ABS(SUM)
C     WRITE(6,19)
19    FORMAT(42HOTHE FOLLOWING IS TVQQ,SUM,ERROR FROM SGEN)
C     WRITE(6,*)TVQQ,SUM,ERROR
      DS=DS*SUM
      DO 20 J=1,NS
```

```
20    S(J)=S(J)+DS                                                     QS039850
      IF(ERROR.GT.TEST.AND.SGEN.EQ.0)SGEN=I                            QS039860
25    CONTINUE                                                         QS039870
      IF(SGEN.EQ.0)RETURN                                              QS039880
30    CONTINUE                                                         QS039890
      RETURN                                                           QS039900
      END                                                              QS039910
      LOGICAL FUNCTION SPGEN (S,Z,C,NS,SP,NSP,SFIN,NMAX)               QS039920
C.....GENERATES TABLE SP HAVING VALUES OF PARAMETER S AS WIDELY SPACED  QS039930
C     AS POSSIBLE AND YET SATISFYING THE FOLLOWING CONDITIONS ON DS:   QS039940
C        1   NSP .LE. NMAX                                             QS039950
C        2   DS  .LE. A/C(S)     (C=CURVATURE)                         QS039960
C        3   DS  .LE. DSMAX                                            QS039970
C        4A  DS(I) .LE. DS(I-1)*RMAX                                   QS039980
C        4B  DS(I) .GE. DS(I-1)/RMAX                                   QS039990
C     FOR THIN SECTIONS, AN ADDITIONAL CONDITION IS:                   QS040000
C            DS  .LE. B*TLOC     (TLOC=LOCAL THICHNESS)                QS040010
C.....SPGEN = .TRUE. IF ALL CONDITIONS HAVE BEEN SATISFIED.             QS040020
                                                                       QS040030
      REAL S(400),C(400),SP(400)                                       QS040040
      COMPLEX Z(400),FZTRP                                             QS040050
      LOGICAL THIN,FIN                                                 QS040060
      COMMON /SPGENC/      A,DSMAX,RMAX,THIN,B,TMIN,DSEND              QS040070
      COMMON /MAN/ DELSMX,PIO2,DELS1,IHUB                              QS040080
      DATA ONE,CMIN/1.0001,1.0E-6/                                     QS040090
                                                                       QS040100
C.....INITIALIZATION SECTION.                                           QS040110
      SPGEN=.FALSE.                                                    QS040120
      J1=MAXO(NSP,2)+1                                                 QS040130
      IF (NSP.GT.1) GO TO 15                                           QS040140
      IF (NSP.LT.1) SP(1)=S(1)                                         QS040150
      DS1=       DELS1                                                 QS040160
10    SP(2)=SP(1)+DS1                                                  QS040170
C     WRITE(6,51)                                                      QS040180
51    FORMAT(30HOTHE FOLLOWING IS S FROM SPGEN//////)                  QS040190
C     WRITE(6,*)S                                                      QS040200
C     WRITE(6,52)                                                      QS040210
52    FORMAT(30HOTHE FOLLOWING IS C FROM SPGEN///////)                 QS040220
C     WRITE(6,*)C                                                      QS040230
C     WRITE(6,53)                                                      QS040240
53    FORMAT(33HOTHE FOLLOWING IS SBAR FROM SPGEN//////)               QS040250
C     WRITE(6,*)SBAR                                                   QS040260
C     WRITE(6,54)                                                      QS040270
54    FORMAT(31HOTHE FOLLOWING IS NS FROM SPGEN////////)               QS040280
C     WRITE(6,*)NS                                                     QS040290
C.....BEGIN MAIN LOOP.                                                  QS040300
15    DO 45 J=J1,NMAX                                                  QS040310
      L=J                                                              QS040320
```

```
20    I=L                                                               QS040330
25    DSLAST=SP(I-1)-SP(I-2)                                            QS040340
      SBAR=SP(I-1)+DSLAST/2.0                                           QS040350
      CA=AMAX1(CMIN,ABS(FNTRP(S,C,SBAR,NS)))                            QS040360
      DSLIM=AMIN1(DS1   ,DSLAST*RMAX)                                   QS040370
      IF (.NOT.THIN) GO TO 30                                           QS040380
      TLOC=CABS(FZTRP(S,Z,SBAR,NS)-FZTRP(S,Z,S(NS)-SBAR,NS))            QS040390
      DSLIM=AMIN1(DSLIM,B*AMAX1(TLOC,TMIN))                             QS040400
30    DSFIN=SFIN-SP(I-1)                                                QS040410
      NEVEN=DSFIN/DSLIM/ONE+1.0                                         QS040420
      DSEVEN=DSFIN/FLOAT(NEVEN)                                         QS040430
      DS=AMIN1(A/CA,DSEVEN)                                             QS040440
      IF (I.NE.J) DS=AMIN1(DS,DSLAST/RMAX)                              QS040450
                                                                        QS040460
C.....CALCULATED VALUE OF DS SATISFIES CONDITIONS 2 THRU 4A.TEST FOR 4B.QS040470
      IF (DS.GE.DSLAST/RMAX) GO TO 40                                   QS040480
                                                                        QS040490
C.....IF CONDITION 4B IS NOT SATISFIED, RE-DO EARLIER INTERVALS         QS040500
C.....USING SMALLER VALUES OF DS.  IF RE-DOING ALL INTERVALS WON'T      QS040510
C.....WORK, START OVER USING SMALLER STARTING VALUE OF DS (DS1).        QS040520
35    L=L-1                                                             QS040530
      IF (L.GE.J1) GO TO 20                                             QS040540
      IF (NSP.GT.1) RETURN                                              QS040550
      DS1=DS1/RMAX                                                      QS040560
      GO TO 10                                                          QS040570
                                                                        QS040580
C.....IF CONDITIONS 2 THRU 4B ARE SATISFIED, TEST FOR FINISH.           QS040590
40    SP(I)=SP(I-1)+DS                                                  QS040600
      FIN=SFIN/SP(I).LE.ONE                                             QS040610
      IF (FIN.AND.DS.GT.DSEND) GO TO 35                                 QS040620
      IF (FIN) GO TO 50                                                 QS040630
      IF (I.GE.J) GO TO 45                                              QS040640
      I=I+1                                                             QS040650
      GO TO 25                                                          QS040660
45    CONTINUE                                                          QS040670
C.....SPGEN =.FALSE. IF CONDITION 1 CANNOT BE SATISFIED.                QS040680
      RETURN                                                            QS040690
                                                                        QS040700
C.....IF CONDITIONS ARE SATISFIED, UPDATE NSP.                          QS040710
50    NSP=I                                                             QS040720
      DELS1=DS                                                          QS040730
      SPGEN=.TRUE.                                                      QS040740
      RETURN                                                            QS040750
      END                                                               QS040760
      COMPLEX FUNCTION DZTRP (A,F,X,NA)                                 QS040770
C.....COMPLEX DERIVATIVE EVALUATION FOR DOUBLE 3-POINT INTERPOLATION.   QS040780
      COMPLEX F(400)                                                    QS040790
      REAL A(400)                                                       QS040800
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      COMMON /NTRPC3/ I1,I2,C(4)                                        QS040810
C.....FIRST EVALUATE FUNCTION COEFFICIENTS.                             QS040820
      CALL FNTRPA (A,X,NA)                                              QS040830
      CALL DNTRPC                                                       QS040840
C.....THEN EVALUATE FUNCTION VALUE.                                     QS040850
C     GO TO 10                                                          QS040860
C     ENTRY DZTRP1 (F)                                                  QS040870
C     DZTRP1=0.                                                         QS040880
10    DZTRP=0.0                                                         QS040890
      J=0                                                               QS040900
      DO 1 I=I1,I2                                                      QS040910
      J=J+1                                                             QS040920
1     DZTRP=DZTRP+C(J)*F(I)                                             QS040930
      RETURN                                                            QS040940
      END                                                               QS040950
      COMPLEX FUNCTION FZTRP (A,F,X,NA)                                 QS040960
C.....COMPLEX FUNCTION EVALUATION BY DOUBLE 3-POINT INTERPOLATION.      QS040970
      COMPLEX F(400)                                                    QS040980
      REAL A(400)                                                       QS040990
      COMMON /NTRPC2/ I1,I2,C(4)                                        QS041000
C.....FIRST EVALUATE FUNCTION COEFFICIENTS.                             QS041010
      CALL FNTRPA (A,X,NA)                                              QS041020
      CALL FNTRPC                                                       QS041030
C.....THEN EVALUATE FUNCTION VALUE.                                     QS041040
C     GO TO 10                                                          QS041050
C     ENTRY FZTRP1 (F)                                                  QS041060
C     FZTRP1=0.                                                         QS041070
10    FZTRP=0.0                                                         QS041080
      J=0                                                               QS041090
      DO 1 I=I1,I2                                                      QS041100
      J=J+1                                                             QS041110
1     FZTRP=FZTRP+C(J)*F(I)                                             QS041120
      RETURN                                                            QS041130
      END                                                               QS041140
      FUNCTION FNTRP (A,F,X,NA)                                         QS041150
C.....FUNCTION EVALUATION FOR DOUBLE 3-POINT INTERPOLATION.             QS041160
      REAL F(400),A(400)                                                QS041170
      COMMON /NTRPC2/ I1,I2,C(4)                                        QS041180
C.....FIRST EVALUATE FUNCTION COEFFICIENTS.                             QS041190
      CALL FNTRPA (A,X,NA)                                              QS041200
      CALL FNTRPC                                                       QS041210
C.....THEN EVALUATE FUNCTION VALUE.                                     QS041220
C     GO TO 5                                                           QS041230
C     ENTRY FNTRP1 (F)                                                  QS041240
C     FNTRP1=0.                                                         QS041250
5     FNTRP=0.0                                                         QS041260
      J=0                                                               QS041270
      DO 10 I=I1,I2                                                     QS041280
```

```
      J=J+1                                                             QS041290
10    FNTRP=FNTRP+C(J)*F(I)                                             QS041300
      RETURN                                                            QS041310
      END                                                               QS041320
      SUBROUTINE DNTRPC                                                 QS041330
C.....CALCULATION OF C COEFFICIENTS FOR DERIVATIVES OF DOUBLE           QS041340
C.....3-POINT INTERPOLATION.                                            QS041350
      COMMON /NTRPC1/ L,I,A11,A12,A13,A14,A22,A23,A24,A33,A34,A44       QS041360
      COMMON /NTRPC3/ I1,I2,C1,C2,C3,C4                                 QS041370
      IF (L.LE.1) GO TO 13                                              QS041380
      IF (L-3) 12,11,10                                                 QS041390
C.....FOR DOUBLE 3-POINT INTERPOLATION.                                 QS041400
10    C1=+(A22+A33+A22)/A23*A33/A12/A13                                 QS041410
      C4=-(A33+A22+A33)/A23*A22/A34/A24                                 QS041420
      P=A23*A23                                                         QS041430
      C2=-((A11+A33+A11)*A33/A12+(A33*A44+A22*A44+A22*A33)/A24)/P       QS041440
      C3=+((A44+A22+A44)*A22/A34+(A22*A11+A33*A11+A33*A22)/A13)/P       QS041450
      GO TO 14                                                          QS041460
C.....FOR SIMPLE 3-POINT INTERPOLATION.                                 QS041470
11    C1=+(A33+A22)/A12/A13                                             QS041480
      C2=-(A33+A11)/A12/A23                                             QS041490
      C3=+(A22+A11)/A13/A23                                             QS041500
      GO TO 14                                                          QS041510
C.....FOR 2-POINT INTERPOLATION.                                        QS041520
12    C1=1.0/A12                                                        QS041530
      C2=-C1                                                            QS041540
      GO TO 14                                                          QS041550
C.....ONLY ONE TABLE VALUE GIVEN.                                       QS041560
13    C1=0.0                                                            QS041570
14    I1=I                                                              QS041580
      I2=I+L-1                                                          QS041590
      RETURN                                                            QS041600
      END                                                               QS041610
      SUBROUTINE FNTRPA(A,X,NA)                                         QS041620
C.....COMMON SUBROUTINE EVALUATES A COEFFICIENTS IN DOUBLE              QS041630
C.....3-POINT INTERPOLATIONS.                                           QS041640
C       L=NO. OF POINTS IN THE FIT                                      QS041650
C       I=INDEX TO FIRST POINT                                          QS041660
      REAL A(400)                                                       QS041670
      COMMON /NTRPC1/ L,I,A11,A12,A13,A14,A22,A23,A24,A33,A34,A44       QS041680
C.....GET I AND L BY TABLE LOOK-UP.                                     QS041690
      L=LIMIT (1,NA,3)                                                  QS041700
      M=MAX0(1,NA-2)                                                    QS041710
      CALL TLU (A,X,NA,J)                                               QS041720
      IF (J.EQ.LIMIT(2,J,M)) L=4                                        QS041730
      I=LIMIT(1,J-1,M)                                                  QS041740
C.....CALCULATE A-ARRAY.                                                QS041750
      A11=A(I)                                                          QS041760
```

```
      A22=A(I+1)                                                        QS041770
      A33=A(I+2)                                                        QS041780
      IF (L.NE.4) IF (L-2) 20,15,10                                     QS041790
      A44=A(I+3)                                                        QS041800
      A14=A11-A44                                                       QS041810
      A24=A22-A44                                                       QS041820
      A34=A33-A44                                                       QS041830
      A44=X-A44                                                         QS041840
10    A13=A11-A33                                                       QS041850
      A23=A22-A33                                                       QS041860
      A33=X-A33                                                         QS041870
15    A12=A11-A22                                                       QS041880
      A22=X-A22                                                         QS041890
      A11=X-A11                                                         QS041900
20    RETURN                                                            QS041910
      END                                                               QS041920
      SUBROUTINE FNTRPC                                                 QS041930
C.....CALCULATION OF C COEFFICIENTS FOR FUNCTION VALUES BY DOUBLE      QS041940
C.....3-POINT INTERPOLATION.                                            QS041950
      COMMON /NTRPC1/L,I,A11,A12,A13,A14,A22,A23,A24,A33,A34,A44       QS041960
      COMMON /NTRPC2/ I1,I2,C1,C2,C3,C4                                 QS041970
      IF (L.LE.1) GO TO 25                                              QS041980
      IF (L-3) 20,15,10                                                 QS041990
C.....FOR DOUBLE 3-POINT INTERPOLATION.                                 QS042000
10    C1=+A33/A23*A22/A12*A33/A13                                       QS042010
      C4=-A22/A23*A33/A34*A22/A24                                       QS042020
      P2=A33/A23*A11/A23                                                QS042030
      P3=A22/A23*A44/A23                                                QS042040
      C2=-A33*(P2/A12+P3/A24)                                           QS042050
      C3=+A22*(P3/A34+P2/A13)                                           QS042060
      GO TO 30                                                          QS042070
C.....FOR SIMPLE 3-POINT INTERPOLATION.                                 QS042080
15    C1=+A22/A12*A33/A13                                               QS042090
      C2=-A11/A12*A33/A23                                               QS042100
      C3=+A11/A13*A22/A23                                               QS042110
      GO TO 30                                                          QS042120
C.....FOR 2-POINT INTERPOLATION.                                        QS042130
20    C1=+A22/A12                                                       QS042140
      C2=-A11/A12                                                       QS042150
      GO TO 30                                                          QS042160
C.....ONLY ONE TABLE VALUE GIVEN.                                       QS042170
25    C1=1.0                                                            QS042180
30    I1=I                                                              QS042190
      I2=I+L-1                                                          QS042200
      RETURN                                                            QS042210
      END                                                               QS042220
      SUBROUTINE TLU (TABLE,ARG,N,I)                                    QS042230
C.....TABLE LOOK UP:  FINDS I SUCH THAT                                 QS042240
```

```
C      ARG.GE.TABLE(I).AND.ARG.LT.TABLE(I+1)
C        IF I=0, ARG.LT.TABLE(1)
C        IF I=N, ARG.GE.TABLE(N)
       REAL TABLE(400)
       I=LIMIT(1,I,N)
       IF (ARG.GE.TABLE(I)) GO TO 15
C.....DESCEND IN TABLE.
10     I=I-1
       IF (I.LE.0) RETURN
       IF (ARG.GE.TABLE(I)) RETURN  .
       GO TO 10
C.....ASCEND IN TABLE.
15     IF (I.GE.N) RETURN
       IF (ARG.LT.TABLE(I+1)) RETURN
       I=I+1
       GO TO 15
       END
       FUNCTION LIMIT (I,J,K)
C.....INTEGER FUNCTION LIMITS J BETWEEN I AND K.
       LIMIT=I
       IF (J.LT.LIMIT) RETURN
       LIMIT=K
       IF (J.GT.LIMIT) RETURN
       LIMIT=J
       RETURN
       END
       LOGICAL FUNCTION XNTRP (A,F,FO,NA,X)
C.....INVERSE FUNCTION FOR DOUBLE 3-POINT INTERPOLATION.

C      GIVEN TABLES A AND F (EACH OF LENGTH NA), THE VALUE OF X IS
C      FOUND FOR WHICH FNTRP (A,F,X,NA)=FO.  ONLY SOLUTIONS LARGER
C      THAN THE ENTRY VALUE OF X ARE CONSIDERED; ONLY THE SMALLEST
C      OF THESE IS RETURNED.  IF NO SOLUTION IS FOUND, XNTRP=.FALSE.
C      AND X IS LEFT UNALTERED.

       REAL A(400),F(400),C(4),R(3)
       INTEGER II(3),REALX,RCMPLX,ICMPLX,TYPE
       LOGICAL LAST,SIZE
       COMMON /NTRPC1/ L,I,EXTRA(10)
       COMMON /NTRPC5/ M,B(4,4)
       DATA REALX,RCMPLX,ICMPLX,EPSLON/0,1,2,1.0E-5/
       COMPLEX FZ(400)
       TYPE=REALX
       GO TO 100

C.....ALTERNATE ENTRIES FOR COMPLEX TYPE FUNCTION TABLES:

C.....RZTRP IS USED TO GET X FOR WHICH REAL(FZTRP(A,F,X,NA))=FO.
```

```
      ENTRY RZTRP (A,FZ,FO,NA,X)
      RZTRP=0.
C.... COMPLEX FZ(NA) THIS WAS MOVED UP TO COMPILE PROPERLY ON NPS 370
      TYPE=RCMPLX
      GO TO 100

C.....IZTRP IS USED TO GET X FOR WHICH AIMAG(FZTRP(A,F,X,NA))=FO.
      ENTRY IZTRP (A,FZ,FO,NA,X)
      IZTRP=0.
      TYPE=ICMPLX

C.....INITIALIZATION.
100   XIN=X
      XMAX=XIN
      DX=0.0

C.....CALCULATE POLYNOMIAL COEFFICIENTS.
1     XMIN=AMAX1(XIN+DX,XMAX-DX)
      CALL BNTRP (A,XMAX,NA)
      LAST=M.GE.NA-1
      IF (LAST) GO TO 2
      MAX=M+L-3
      XMAX=A(MAX)
2     DO 3 J=1,L
      C(J)=0.0
      DO 3 N=1,L
      IN=I+N-1
      IF (TYPE.EQ.REALX) C(J)=C(J)+B(N,J)*F(IN)
      IF (TYPE.EQ.RCMPLX) C(J)=C(J)+B(N,J)*REAL(FZ(IN))
      IF (TYPE.EQ.ICMPLX) C(J)=C(J)+B(N,J)*AIMAG(FZ(IN))
3     CONTINUE
      C(1)=C(1)-FO
      IF(L.EQ.4.AND.ABS(C(L)).LT.1.E-04)L=3
      LL=L
4     IF (LL.LT.2) GO TO 8
      IF (C(LL).NE.0.0) GO TO 5
      LL=LL-1
      GO TO 4

C.....GET ROOTS OF POLYNOMIAL.
5     NR=1
      IF (LL.EQ.2) R(1)=-C(1)/C(2)
      IF (LL.EQ.3) NR=NRRTS2(C,R)
      IF (LL.EQ.4) NR=NRRTS3(C,R)

C.....TEST ROOTS OF POLYNOMIAL.
      IF (NR.LE.0) GO TO 8
      IF (.NOT.SIZE(R,II,NR)) CALL ORDER (R,II,NR)
```

```
      DO 6 N=1,NR                                                       QS043210
      XVAL=R(N)+A(M)                                                    QS043220
      IF (XVAL.GT.XMIN) GO TO 7                                         QS043230
6     CONTINUE                                                          QS043240
      GO TO 8                                                           QS043250
7     IF (LAST .OR. XVAL.LE.XMAX) X=XVAL                                QS043260
      IF(ABS(XVAL-XMAX).LE.1.E-04)X=XVAL                                QS043270
8     XNTRP=X.NE.XIN                                                    QS043280
                                                                        QS043290
C.....IF NO SOLUTION FOUND, KEEP SEARCHING.                              QS043300
9     IF (XNTRP.OR.LAST) RETURN                                         QS043310
      DX=EPSLON*(ABS(XMAX)+ABS(XMIN))                                   QS043320
      GO TO 1                                                           QS043330
      END                                                               QS043340
      SUBROUTINE BNTRP (A,X,NA)                                         QS043350
C.....CALCULATION OF MATRIX B BY WHICH COEFFICIENTS OF THE POLYNOMIAL    QS043360
C     USED IN DOUBLE 3-POINT INTERPOLATION MAY BE OBTAINED.             QS043370
C                                                                       QS043380
C     IF     F(X) = C(1) + C(2)*(X-A(M)) + C(3)*(X-A(M))**2 +...        QS043390
C                                                                       QS043400
C     IS THE POLYNOMIAL USED IN THE NEIGHBORHOOD OF X, THE COEFFICIENTS QS043410
C     CAN BE OBTAINED FROM MATRIX B BY:                                 QS043420
C                                                                       QS043430
C            C(J) = B(1,J)*F(I) + B(2,J)*F(I+1) +...                    QS043440
C                                                                       QS043450
C     FOR A TOTAL OF L VALUES OF C AND F (AT MOST 4) WHERE L AND I ARE  QS043460
C     FOUND IN COMMON /NTRPC1/ AND M AND B ARE FOUND IN COMMON /NTRPC5/.QS043470
                                                                        QS043480
      REAL A(NA)                                                        QS043490
      COMMON /NTRPC1/ L,I,A11,A12,A13,A14,A22,A23,A24,A33,A34,A44       QS043500
      COMMON /NTRPC5/ M,B11,B21,B31,B41,B12,B22,B32,B42,B13,B23,B33,    QS043510
     1                B43,B14,B24,B34,B44                               QS043520
                                                                        QS043530
C.....SET UP COMMON BLOCK /NTRPC1/                                       QS043540
      CALL FNTRPA (A,X,NA)                                              QS043550
      IF (L.GT.1) GO TO 2                                               QS043560
                                                                        QS043570
C.....ENTER HERE FOR ONLY ONE COEFFICIENT.                               QS043580
1     M=I                                                               QS043590
      B11=1.0                                                           QS043600
      RETURN                                                            QS043610
                                                                        QS043620
C.....ENTER HERE FOR 2 OR MORE COEFFICIENTS.                             QS043630
2     M=I+1                                                             QS043640
      Q=1.0/A12                                                         QS043650
      IF (L.GT.2) GO TO 3                                               QS043660
      B12=Q                                                             QS043670
      B22=-Q                                                            QS043680
```

```
      GO TO 24

C.....ENTER HERE FOR 3 OR MORE COEFFICIENTS.
3     P=1.0/A23
      IF (L.GT.3) GO TO 4
      B13=Q/A13
      B23=-Q*P
      B33=P/A13
      GO TO 34

C.....ENTER HERE FOR 4 COEFFICIENTS.
4     P2=P*P
      B14=P*Q/A13
      B24=-P2/A12-P2/A24
      B34=P2/A34+P2/A13
      B44=-P/A34/A24
      B13=(Q+Q)/A13
      B23=-P*(Q+Q)-P/A24
      B33=P2*(A24/A34+(A23-A12)/A13)
      B43=-1.0/A34/A24
      B41=0.0
      B42=0.0
34    B12=A23/A12/A13
      B22=P-Q
      B32=-A12/A13/A23
      B31=0.0
24    B11=0.0
      B21=1.0
      RETURN
      END
      INTEGER FUNCTION NRRTS3 (C,R)
C.....FINDS REAL ROOTS R, OF A CUBIC WITH COEFFICIENTS C, WHEN:
C             C(1) + C(2)*X + C(3)*X**2 + C(4)*X**3 = 0.0

      REAL C(4),R(3),K1,K2
      DATA THIRD,K1,K2/0.3333333,2.094395,4.188790/
      QRT(ARG)=SIGN(ABS(ARG)**THIRD,ARG)

C.....CONVERT TO NORMAL FORM AND CALCULATE NORMAL COEFFICIENTS.
      CNORM=3.0*C(4)
      P=C(3)/CNORM
      Q=C(2)/CNORM
      B=P**3-1.5*(P*Q-C(1)/CNORM)
      B2=B**2
      A=Q-P*P
      A3=A**3
      RAD=B2+A3
      IF (RAD) 3,2,1
```

```
C.....THERE IS ONE REAL ROOT.
1     NRRTS3=1
      IF (RAD.NE.0.0) RAD=SQRT(RAD)
      A=-B+RAD
      B=-B-RAD
      IF (A.NE.0.0) A=QRT(A)
      IF (B.NE.0.0) B=QRT(B)
      R(1)=A+B
      GO TO 10

C.....THERE ARE TWO REAL ROOTS.
2     NRRTS3=2
      IF (B.EQ.0.0) GO TO 1
      R(1)=QRT(B)
      R(2)=-2.0*R(1)
      GO TO 10

C.....THERE ARE THREE REAL ROOTS.
3     NRRTS3=3
      PHI= ARCOS(SIGN(SQRT(-B2/A3),-B))/3.0
      CR=2.0*SQRT(-A)
      R(1)=CR*COS(PHI)
      R(2)=CR*COS(PHI+K1)
      R(3)=CR*COS(PHI+K2)

C.....CONVERT BACK TO ORIGINAL FORM.
10    DO 11 I=1,NRRTS3
11    R(I)=R(I)-P
      RETURN

      ENTRY NRRTS2 (C,R)
C.....FINDS REAL ROOTS R, OF A QUADRATIC WITH COEFFICIENTS C, WHEN:
C             C(1) + C(2)*X + C(3)*X**2 + = 0.0


C.....CALCULATE RADICAL.
      RAD=C(2)**2-4.0*C(3)*C(1)
      IF (RAD) 21,22,23

C.....NO REAL ROOTS.
21    NRRTS3=0
      NRRTS2=0
      RETURN
C.....ONE REAL ROOT.
22    NRRTS3=1
      R(1)=-C(2)/2.0/C(3)
      NRRTS2=1
```

```
      RETURN
C.....TWO REAL ROOTS.
23    NRRTS3=2
      RAD=SQRT(RAD)
      TWOA=2.0*C(3)
      R(1)=-(RAD+C(2))/TWOA
      R(2)=+(RAD-C(2))/TWOA
      NRRTS2=2
      RETURN
      END
      LOGICAL FUNCTION SIZE (X,I,N)
C.....CREATES THE POINTER ARRAY I, ORDERED BY SIZE OF X.
C.....VALUE IS .TRUE. IF X ARRAY IS IN ORDER.
      DIMENSION X(3),I(3)
      COMPLEX Z(3),ZS
      SIZE=.TRUE.
      DO 2 J=1,N
      K=J
1     IF (K.LE.1) GO TO 2
      L=I(K-1)
      IF (X(J).GE.X(L)) GO TO 2
      I(K)=L
      K=K-1
      SIZE=.FALSE.
      GO TO 1
2     I(K)=J
      RETURN
      ENTRY ORDER (X,I,N)
      ORDER=0.
C.....REARRANGES X ARRAY ACCORDING TO POINTER ARRAY I.
      DO 14 J=1,N
      IF (I(J).LE.0) GO TO 13
      M=J
      S=X(M)
11    L=I(M)
      I(M)=-L
      IF (L.EQ.J) GO TO 12
      X(M)=X(L)
      M=L
      GO TO 11
12    X(M)=S
13    I(J)=IABS(I(J))
14    CONTINUE
      RETURN
      ENTRY ZORDER (Z,I,N)
      ZORDER=0.
C.....REARRANGES Z (COMPLEX) ARRAY ACCORDING TO POINTER ARRAY I.
```

```
C     COMPLEX Z(N),ZS THIS WAS MOVED UP TO COMPILE PROPERLY ON NPS 370
      DO 24 J=1,N
      IF (I(J).LE.0) GO TO 23
      M=J
      ZS=Z(M)
21    L=I(M)
      I(M)=-L
      IF (L.EQ.J) GO TO 22
      Z(M)=Z(L)
      M=L
      GO TO 21
22    Z(M)=ZS
23    I(J)=IABS(I(J))
24    CONTINUE
      RETURN
      END
      SUBROUTINE PJGRID(ZET,ET,ZCAM,IMAXY,PITCH)


C             ELECTROSTATIC ANALOG GRID GENERATOR

C                       J. J. ADAMCZYK
C             NASA LEWIS RESEARCH CENTER 1980


C                   (SEE REF. 2, QSONIC USERS MANUAL)


      COMMON/ENTIRE/  X(100,30),Y(100,30),ETA(100,30),ZETA(100,30)
      COMMON/CROSS/XQ(4,100),YQ(4,100),EQ(4,100),ZQ(4,100),ZETB(100),
     1STREN(63),FUN(100),GUN1(100),ARG(100),ZBODY(63),DTREN(63)
      COMMON/GEOM/NZGRID,NEGRID,RLE,RTE,C,CHORB,XUPS,XDNS,STAG,CC,CAP(4)
     1,PI
     1,RNK,VB,KN,NUM
      COMPLEX A,B,ZO,ZA,ZB,ZTEMP,ZTEMQ
      COMPLEX SUM3,SUM4,SUM5,SUM6,STREN
      COMPLEX SUMD,HSIN
      COMPLEX ZTEL,AI,HTAN,Z,SUM
      COMPLEX SOUR,ZCAM,ZBODY,ZPET
      COMPLEX ZST
      DOUBLE PRECISION DTREN,BINF
      DIMENSION ZPET(100,30),ZCAM(100),ET(100),ZET(100)
      EQUIVALENCE (ZPET(1,1),ETA(1,1))
      COMMON/CRHOSS/ BINF(63,63),SOUR(63,63)
      LOGICAL XNTRP,TEST
      NETAO=50
      NZETO=50
      NZET4=50
```

```
      IMID=1
      NUMX=31
      NUMY=14
      NUMZ=16
C
C     NZGRID MUST BE ODD
C
      AI=CMPLX(0.0,1.0)
      PI=3.1415927
      CHORD=CHORB*COS(STAG)
      STAG=STAG*180./PI
      S=PITCH
      WRITE(6,1006) NEGRID,NZGRID,IMAXY
1006  FORMAT(5X,'NEGRID= ',I3,' NZGRID,ODD= ',I3,' IMAXY= ',I3)
10    CONTINUE
      WRITE(6,1020)
1020  FORMAT(10X,'SURFACE COORDINATES')
      WRITE(6,1030) (ZCAM(I),I=1,NUM)
1030  FORMAT(7X,2F12.7)
      WRITE(6,1040) NUM,PITCH,CHORD,STAG
1040  FORMAT(4X,'NUMBER OF BODY POINTS',I5,10X,'PITCH',F12.7,10X,' CHO '
     1,F12.7,' STAGGER',F12.7)
      ZST=ZCAM(1)
      DO 25 I=1,NUM
      ZCAM(I)=ZCAM(I)-ZST
25    CONTINUE
      MUM=NUM-1
      PSAVE=PITCH
      PITCH=2.0*PITCH
      XMAX=0.0
      IMAX=1
      DO 6000 I=1,NUM
      IF(XMAX .LE. REAL(ZCAM(I))) XMAX=REAL(ZCAM(I))
      IF(XMAX .LE. REAL(ZCAM(I))) IMAX=I
6000  CONTINUE
      DO 30 I=1,MUM
      IF(IMID .EQ. 1) ZBODY(I)=(ZCAM(I)+ZCAM(I+1))/2.0
      DO 30 J=1,MUM
      A=ZCAM(J)
      B=ZCAM(J+1)
      ZO=(A+B)/2.0
      ZA=CLOG(PI/PITCH*(ZBODY(I)-A))
      ZB=CLOG(PI/PITCH*(ZBODY(I)-B))
      IF(I .EQ. J) ZA=ZA
      IF(I .EQ. J  .AND. AIMAG(ZB) .LT. 0.0 .AND. J .LT. IMAX) ZB=ZB+2.0
     **AI*PI
      IF(I .LT. J .AND. AIMAG(ZA) .LT. 0.0 .AND. I .LT. IMAXY) ZA=ZA+2.0
     **AI*PI
```

```
      IF(I .LT. J .AND. AIMAG(ZB) .LT. 0.0 .AND. I .LT. IMAXY) ZB=ZB+2.0QS046090
     **AI*PI                                                            QS046100
      IF(I .GT. J) ZA=ZA                                                QS046110
      IF(I .GT. J) ZB=ZB                                                QS046120
      IF(I .GE. J .AND. J .GE. IMAX/2.0 .AND. AIMAG(ZA) .GT. PI/2.0) ZA=QS046130
     *ZA-2.0*PI*AI                                                      QS046140
      IF(I .GT. J .AND. J.GE. IMAX/2.0 .AND. AIMAG(ZB) .GT. PI/2.0)ZB=ZBQS046150
     *-2.0*PI*AI                                                        QS046160
 4000 CONTINUE                                                          QS046170
      SOUR(I,J)=(ZBODY(I)-A)*ZA-(ZBODY(I)-B)*ZB+(A-B)                   QS046180
      ZTEL=(ZBODY(I)-ZO)*PI/PITCH                                       QS046190
      HTAN=(CEXP(ZTEL)-CEXP(-ZTEL))/(CEXP(ZTEL)+CEXP(-ZTEL))            QS046200
      IF(CABS(ZTEL) .EQ. 0.0) SOUR(I,J)=SOUR(I,J)                       QS046210
      IF(CABS(ZTEL) .NE. 0.0) SOUR(I,J)=SOUR(I,J)+CLOG(HTAN/ZTEL)*(B-A) QS046220
      A1=ABS(REAL(B-A))                                                 QS046230
      A2=ABS(AIMAG(B-A))                                                QS046240
      IF(A1 .GE. A2) BINF(I,J)=REAL(SOUR(I,J))+AIMAG(B-A)/REAL(B-A)*AIMAQS046250
     *G(SOUR(I,J))                                                      QS046260
      IF(A1 .LT. A2) BINF(I,J)=-AIMAG(SOUR(I,J))-REAL(B-A)/AIMAG(B-A)*REQS046270
     *AL(SOUR(I,J))                                                     QS046280
   30 CONTINUE                                                          QS046290
C                                                                       QS046300
C     SOLUTION OF LINEAR EQUATIONS FOR ELECTROSTATIC CHARGE STRENGTH DISQS046310
C     TRIBUTION                                                         QS046320
C                                                                       QS046330
      IF(NUM .GT. 1) GO TO 40                                           QS046340
      STREN(1)=1.0/BINF(1,1)                                            QS046350
      GO TO 50                                                          QS046360
   40 CONTINUE                                                          QS046370
      DO 45 I=1,MUM                                                     QS046380
      DTREN(I)=1.0D0                                                    QS046390
   45 CONTINUE                                                          QS046400
                                                                        QS046410
                                                                        QS046420
      CALL CHLSKY(BINF,DTREN,MUM)                                       QS046430
   50 CONTINUE                                                          QS046440
                                                                        QS046450
                                                                        QS046460
                                                                        QS046470
      DO 51 I=1,MUM                                                     QS046480
      A=ZCAM(I)                                                         QS046490
      B=ZCAM(I+1)                                                       QS046500
      A1=ABS(REAL(B-A))                                                 QS046510
      A2=ABS(AIMAG(B-A))                                                QS046520
      STEMP=DTREN(I)                                                    QS046530
      IF(A1 .GE. A2)  STREN(I)=STEMP-AI*STEMP*AIMAG(B-A)/REAL(B-A)      QS046540
      IF(A1 .LT. A2) STREN(I)=-STEMP*REAL(B-A)/AIMAG(B-A)+AI*STEMP      QS046550
   51 CONTINUE                                                          QS046560
```

```
      DO 55 I=1,MUM
      SUM2=0.0
      SUM7=0.0
      DO 56 J=1,MUM
      A=ZCAM(J)
      B=ZCAM(J+1)
      A1=ABS(REAL(B-A))
      A2=ABS(AIMAG(B-A))
      IF(A1 .GE. A2) SUM2=SUM2+BINF(I,J)*REAL(STREN(J))
      IF(A1 .LT. A2) SUM2=SUM2+BINF(I,J)*AIMAG(STREN(J))
      FUN1=AIMAG(SOUR(I,J))-REAL(SOUR(I,J))*AIMAG(B-A)/REAL(B-A)
      SUM7=SUM7+REAL(STREN(J))*FUN1
56    CONTINUE
      ZETB(I)=SUM7
55    CONTINUE
      CHORX=CHORD
      DELX=3.0*CHORX/(NUMX-1.0)
      DO 60 I=1,1
      DO 60 J=1,NUMY
      X(I,J)=-2.0*PSAVE
60    CONTINUE
      DELY=PSAVE/(NUMY-2)
      DO 70 I=1,1
      DO 70 J=1,NUMY
      Y(I,J)=DELY*(J-2)
      IF(J .EQ. 1) Y(I,J)=-0.00001
      IF(J .EQ. 2) Y(I,J)=0.00001
      SUM=0.0
      Z=X(I,J)+AI*Y(I,J)
      IF(X(I,J) .LT. 0.0 .OR. X(I,J) .GT. XMAX) GO TO 7031
      DO 7060 L=1,IMAX
      IF(X(I,J) .GE. REAL(ZCAM(L)) .AND. X(I,J) .LE.  REAL(ZCAM(L+1))) G
     *O TO 7080
7060  CONTINUE
7080  CONTINUE
      L1=L
      DO 7100 L=IMAX,NUM
      IF(X(I,J) .LE. REAL(ZCAM(L)) .AND. X(I,J) .GE. REAL(ZCAM(L+1))) GO
     * TO 7120
7100  CONTINUE
7120  CONTINUE
      L2=L
      YA=AIMAG(ZCAM(L1))
      YB=AIMAG(ZCAM(L1+1))
      XA=REAL(ZCAM(L1))
      XB=REAL(ZCAM(L1+1))
      Y1=YA+(YB-YA)/(XB-XA)*(X(I,J)-XA)
      YA=AIMAG(ZCAM(L2))
```

```
      YB=AIMAG(ZCAM(L2+1))
      XA=REAL(ZCAM(L2))
      XB=REAL(ZCAM(L2+1))
      Y2=YA+(YB-YA)/(XB-XA)*(X(I,J)-XA)
 7031 CONTINUE
      DO 75 IX=1,MUM
      A=ZCAM(IX)
      B=ZCAM(IX+1)
      ZA=CLOG(PI/PITCH*(Z-A))
      ZB=CLOG(PI/PITCH*(Z-B))
      IF(X(I,J) .GT. 0.0) GO TO 7000
      IFLA=1
      IF(Y(I,J) .GE. 0.0) GO TO 7010
      ZA=ZA
      ZB=ZB
      GO TO 7020
 7010 CONTINUE
      IF(AIMAG(ZA) .LT. 0.0) ZA=ZA+2.0*AI*PI
      IF(AIMAG(ZB) .LT. 0.0) ZB=ZB+2.0*AI*PI
      GO TO 7020
 7000 CONTINUE
      IF(X(I,J) .GT. XMAX) GO TO 7040
      IF(Y(I,J) .LT. Y1 .AND. Y(I,J) .GT. Y2) IFLA=2
      IF(Y(I,J) .LT. Y1) GO TO 7140
      IF(AIMAG(ZA) .LT. -PI/2.0) ZA=ZA+2.0*AI*PI
      IF(AIMAG(ZB) .LT. -PI/2.0) ZB=ZB+2.0*AI*PI
      GO TO 7020
 7140 CONTINUE
      IF(Y(I,J) .LE. Y2) GO TO 7160
      IF(AIMAG(ZA) .LT. 0.0 .AND. IX .GE. IMAX) ZA=ZA+2.0*AI*PI
      IF(AIMAG(ZB) .LT. 0.0 .AND. IX .GE. IMAX) ZB=ZB+2.0*AI*PI
      GO TO 7020
 7160 CONTINUE
      ZA=ZA
      ZB=ZB
      IF(IX .GE. IMAXY .AND. AIMAG(ZA) .GT. PI/2.0) ZA=ZA-2.0*PI*AI
      IF(IX .GE. IMAXY .AND. AIMAG(ZB) .GT. PI/2.0) ZB=ZB-2.0*PI*AI
      GO TO 7020
 7040 CONTINUE
      IFLA=1
      ZA=ZA
      ZB=ZB
 7020 CONTINUE
 5000 CONTINUE
      SUM=SUM+STREN(IX)*(A-B+(Z-A)*ZA-(Z-B)*ZB)
      ZO=(A+B)/2.0
      ZTEL=(Z-ZO)*PI/PITCH
      HTAN=(CEXP(ZTEL)-CEXP(-ZTEL))/(CEXP(ZTEL)+CEXP(-ZTEL))
```

```
      SUM=SUM+STREN(IX)*CLOG(HTAN/ZTEL)*(B-A)
      IF(I .GT. 1 .AND. I .LT. NUMX) GO TO 3010
      SUM3=(A-B)+(Z-A)*ZA-(Z-B)*ZB
      SUM3= SUM3*STREN(IX)
      SUM4=CLOG(HTAN/ZTEL)*(B-A)
      SUM4= SUM4*STREN(IX)
      SUM5=CLOG(1.0/ZTEL)*(B-A)
      SUM5= SUM5*STREN(IX)
      SUM6=CLOG(HTAN)*(B-A)
      SUM6= SUM6*STREN(IX)
3010  CONTINUE
75    CONTINUE
      ETA(I,J)=REAL(SUM)
      IF(X(I,J) .LT.  XMAX .AND. X(I,J) .GT. 0.0 .AND. Y(I,J) .LT. Y1 .
     *AND
     1.Y(I,J) .GT. Y2) ETA(I,J)=1.05
      ZETA(I,J)=AIMAG(SUM)
70    CONTINUE
      NUMD=NUMY-1
      DO 310 ID=1,NUMD
      ARG(ID)=Y(1,ID+1)
      FUN(ID)=ETA(1,ID+1)
      GUN1(ID)=ZETA(1,ID+1)
310   CONTINUE
      FO=0.0
      YSTAR2=.95*PSAVE/2.
      TEST=XNTRP(ARG,FUN,FO,NUMD,YSTAR2)
      ZETA2=FNTRP(ARG,GUN1,YSTAR2,NUMD)
      ETEST=0.0
      ITEST=1
      DO 330 I=1,NUMD
      IF(ETEST .LE. ETA(1,I+1)) ETEST=ETA(1,I+1)
      IF(ETEST .LE. ETA(1,I+1)) ITEST=I
330   CONTINUE
      IF(ITEST .EQ. 1) ITEST=2
      AQ1=ZETA(1,ITEST+1)
      DELT=Y(1,4)-Y(1,2)
      AQ2=(ZETA(1,ITEST+2)-ZETA(1,ITEST))/(2.0*DELT)
      AQ3=(ZETA(1,ITEST+2)+ZETA(1,ITEST)-2.0*ZETA(1,ITEST+1))/(2.0*DELT*
     **2)
      BQ2=(ETA(1,ITEST+2)-ETA(1,ITEST))/(2.0*DELT)
      BQ3=(ETA(1,ITEST+2)+ETA(1,ITEST)-2.0*ETA(1,ITEST+1))/(2.0*DELT**2)
      YLMAX=-BQ2/(2.0*BQ3)
      ZETA4=AQ1+AQ2*YLMAX+AQ3*YLMAX**2
      DELZ=ZETA(1,2)-ZETA(1,1)
      DO 360 I=1,MUM
      ARG(I)=ZETB(I)
      FUN(I)=REAL(ZBODY(I))
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```
360   CONTINUE
      XBOD1=FNTRP(ARG,FUN,ZETA4,MUM)
      XBOD3=FNTRP(ARG,FUN,0.0,MUM)
      DO 370 I=1,MUM
      FUN(I)=AIMAG(ZBODY(I))
370   CONTINUE
      YBOD1=FNTRP(ARG,FUN,ZETA4,MUM)
      YBOD3=FNTRP(ARG,FUN,0.0,MUM)
      ILIM=MUM+2
      XQ(1,1)=XBOD1
      XQ(1,ILIM)=XBOD1
      YQ(1,1)=YBOD1
      YQ(1,ILIM)=YBOD1
      ZQ(1,1)=ZETA4
      ZQ(1,ILIM)=-ZETA4
      EQ(1,1)=1.0
      EQ(1,ILIM)=1.0
      DO 380 I=1,MUM
      IF(ZETB(I) .GT. ZETA4)  GO TO 390
380   CONTINUE
390   CONTINUE
      ISTART=I
      DO 410 I=ISTART,MUM
      IL=I-ISTART+2
      XQ(1,IL)=REAL(ZBODY(I))
      YQ(1,IL)=AIMAG(ZBODY(I))
      ZQ(1,IL)=ZETB(I)
      EQ(1,IL)=1.0
410   CONTINUE
      IEND=ISTART-1
      DO 420 I=1,IEND
      IL=MUM-ISTART+2+I
      XQ(1,IL)=REAL(ZBODY(I))
      YQ(1,IL)=AIMAG(ZBODY(I))
      ZQ(1,IL)=ZETB(I)-DELZ
      EQ(1,IL)=1.0
420   CONTINUE

C      DETERMINE LOCATION OF PERIODIC BOUNDARY POINTS

      DO 110 IL=2,4
      IF(IL .EQ. 2) YQ(2,1)=YSTAR2
      IF(IL .EQ. 2) XQ(2,1)=-1.50*PSAVE
      IF(IL .EQ. 2) EQ(2,1)=0.0
      IF(IL .EQ. 2) ZQ(2,1)=ZETA2
      IF(IL .EQ. 2) DELX=(CHORX+3.*PSAVE)/(NETA0-1.0)
      IF(IL .EQ. 2) IEND=NETA0
```

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      IF(IL .EQ. 2) ETAO=0.0                                            QS048490
      IF(IL .EQ. 3) YQ(3,1)=YBOD3                                       QS048500
      IF(IL .EQ. 3) XQ(3,1)=XBOD3                                       QS048510
      IF(IL .EQ. 3) EQ(3,1)=1.0                                         QS048520
      IF(IL .EQ. 3) ZQ(3,1)=0.0                                         QS048530
      IF(IL .EQ. 3) DELX=(2.0*PSAVE)/(NZETO-1.0)                        QS048540
      IF(IL .EQ. 3) IEND=NZETO                                          QS048550
      IF(IL .EQ. 3) ZETAO=0.0                                           QS048560
      IF(IL .EQ. 4) YQ(4,1)=YBOD1                                       QS048570
      IF(IL .EQ. 4) XQ(4,1)=XBOD1                                       QS048580
      IF(IL .EQ. 4) EQ(4,1)=1.0                                         QS048590
      IF(IL .EQ. 4) ZQ(4,1)=ZETA4                                       QS048600
      IF(IL .EQ. 4) DELX=(-2.0*PSAVE-XBOD1)/(NZET4-1.0)                 QS048610
      IF(IL .EQ. 4) IEND=NZET4                                          QS048620
      IF(IL .EQ. 4) ZETAO=ZETA4                                         QS048630
      DO 110 I=2,IEND                                                   QS048640
      XQ(IL,I)=XQ(IL,I-1)+DELX                                          QS048650
      YQ(IL,I)=YQ(IL,I-1)                                               QS048660
      DO 120 ITOL=1,200                                                 QS048670
      SUM=0.0                                                           QS048680
      SUMD=0.0                                                          QS048690
      Z=XQ(IL,I)+AI*YQ(IL,I)                                            QS048700
      IF(XQ(IL,I) .LT. 0.0 .OR. XQ(IL,I) .GT. XMAX) GO TO 130           QS048710
      DO 140 L=1,IMAX                                                   QS048720
      IF(XQ(IL,I) .GE. REAL(ZCAM(L)) .AND. XQ(IL,I) .LE. REAL(ZCAM(L+1))QS048730
     *) GO TO 150                                                       QS048740
  140 CONTINUE                                                          QS048750
  150 CONTINUE                                                          QS048760
      L1=L                                                              QS048770
      DO 160 L=IMAX,NUM                                                 QS048780
      IF(XQ(IL,I) .LE. REAL(ZCAM(L)) .AND. XQ(IL,I) .GE. REAL(ZCAM(L+1))QS048790
     *) GO TO 170                                                       QS048800
  160 CONTINUE                                                          QS048810
  170 CONTINUE                                                          QS048820
      L2=L                                                              QS048830
      YA=AIMAG(ZCAM(L1))                                                QS048840
      YB=AIMAG(ZCAM(L1+1))                                              QS048850
      XA=REAL(ZCAM(L1))                                                 QS048860
      XB=REAL(ZCAM(L1+1))                                               QS048870
      Y1=YA+(YB-YA)/(XB-XA)*(XQ(IL,I)-XA)                               QS048880
      YA=AIMAG(ZCAM(L2))                                                QS048890
      YB=(AIMAG(ZCAM(L2+1)))                                            QS048900
      XA=REAL(ZCAM(L2))                                                 QS048910
      XB=REAL(ZCAM(L2+1))                                               QS048920
      Y2=YA+(YB-YA)/(XB-XA)*(XQ(IL,I)-XA)                               QS048930
  130 CONTINUE                                                          QS048940
      DO 180 IX=1,MUM                                                   QS048950
      A=ZCAM(IX)                                                        QS048960
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      B=ZCAM(IX+1)                                                      QS048970
      ZA=CLOG(PI/PITCH*(Z-A))                                           QS048980
      ZB=CLOG(PI/PITCH*(Z-B))                                           QS048990
      IF(XQ(IL,I) .GT. 0.0) GO TO 190                                   QS049000
      IF(YQ(IL,I) .GE.  0.0) GO TO 200                                  QS049010
      ZA=ZA                                                             QS049020
      ZB=ZB                                                             QS049030
      GO TO 210                                                         QS049040
  200 CONTINUE                                                          QS049050
      IF(AIMAG(ZA) .LT. 0.0) ZA=ZA+2.0*AI*PI                            QS049060
      IF(AIMAG(ZB) .LT. 0.0) ZB=ZB+2.0*AI*PI                            QS049070
      GO TO 210                                                         QS049080
  190 CONTINUF                                                          QS049090
      IF(XQ(IL,I) .GT. XMAX) GO TO 220                                  QS049100
      IF(YQ(IL,I) .LT. Y1) GO TO 230                                    QS049110
      IF(AIMAG(ZA) .LT. -PI/2.0) ZA=ZA+2.0*AI*PI                        QS049120
      IF(AIMAG(ZB) .LT. -PI/2.0) ZB=ZB+2.0*AI*PI                        QS049130
      GO TO 210                                                         QS049140
  230 CONTINUE                                                          QS049150
      IF(YQ(IL,I) .LE. Y2) GO TO 240                                    QS049160
      IF(AIMAG(ZA) .LT. 0.0 .AND. IX .GE. IMAX) ZA=ZA+2.0*AI*PI         QS049170
      IF(AIMAG(ZB) .LT. 0.0 .AND. IX .GE. IMAX) ZB=ZB+2.0*AI*PI         QS049180
      GO TO 210                                                         QS049190
  240 CONTINUE                                                          QS049200
      ZA=ZA                                                             QS049210
      ZB=ZB                                                             QS049220
      IF(IX .GE. IMAXY .AND . AIMAG(ZA) .GT. PI/2.0) ZA=ZA-2.0*PI*AI    QS049230
      IF(IX .GE. IMAXY .AND. AIMAG(ZB) .GT. PI/2.0) ZB=ZB-2.0*PI*AI     QS049240
      GO TO 210                                                         QS049250
  220 CONTINUE                                                          QS049260
      ZA=ZA                                                             QS049270
      ZB=ZB                                                             QS049280
  210 CONTINUE                                                          QS049290
      SUM=SUM+STREN(IX)*(A-B+(Z-A)*ZA-(Z-B)*ZB)                         QS049300
      SUMD=SUMD+STREN(IX)*(ZA-ZB)                                       QS049310
      ZO=(A+B)/2.0                                                      QS049320
      ZTEL=(Z-ZO)*PI/PITCH                                              QS049330
      HTAN=(CEXP(ZTEL)-CEXP(-ZTEL))/(CEXP(ZTEL)+CEXP(-ZTEL))            QS049340
      HSIN=0.5*(CEXP(ZTEL*2.0)-CEXP(-ZTEL*2.0))                         QS049350
      SUM=SUM+STREN(IX)*CLOG(HTAN/ZTEL)*(B-A)                           QS049360
      SUMD=SUMD+STREN(IX)*(PI/PSAVE/HSIN-1.0/(Z-ZO))*(B-A)              QS049370
  180 CONTINUE                                                          QS049380
      ETAF=REAL(SUM)                                                    QS049390
      ZETAF=AIMAG(SUM)                                                  QS049400
      ETAFD=AIMAG(SUMD)                                                 QS049410
      ZETAFD=-REAL(SUMD)                                                QS049420
      F1=ETAO-ETAF                                                      QS049430
      G1=ZETAO-ZETAF                                                    QS049440
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      DELY1=-F1/ETAFD                                              QS049450
      DELY2=-G1/ZETAFD                                             QS049460
      IF(IL .EQ. 2) DELT=DELY1                                     QS049470
      IF(IL .GT. 2) DELT=DELY2                                     QS049480
      YQ(IL,I)=YQ(IL,I)+DELT                                       QS049490
      IF(ABS(DELT) .LT. 1.E-06) GO TO 250                          QS049500
120   CONTINUE                                                     QS049510
250   CONTINUE                                                     QS049520
      IF(IL .EQ. 2) EQ(IL,I)=0.0                                   QS049530
      IF(IL .EQ. 2) ZQ(IL,I)=ZETAF                                 QS049540
      IF(IL .EQ. 3) EQ(IL,I)=ETAF                                  QS049550
      IF(IL .EQ.3) ZQ(IL,I)=0.0                                    QS049560
      IF(IL .EQ. 4) EQ(IL,I)=ETAF                                  QS049570
      IF(IL .EQ. 4) ZQ(IL,I)=ZETA4                                 QS049580
110   CONTINUE                                                     QS049590
                                                                   QS049600
                                                                   QS049610
                                                                   QS049620
                                                                   QS049630
      NEND=2*NZGRID-1                                              QS049640
      DO 500 I=1,NEND                                              QS049650
      DO 500 J=1,NEGRID                                            QS049660
      ETA(I,J)=0.0                                                 QS049670
      ZETA(I,J)=0.0                                                QS049680
      X(I,J)=0.0                                                   QS049690
      Y(I,J)=0.0                                                   QS049700
500   CONTINUE                                                     QS049710
      DELZ=ZQ(4,1)/(NZGRID-1.0)                                    QS049720
      DELE=1.0/(NEGRID-1.0)                                        QS049730
      DO 510 I=1,NETAO                                             QS049740
      ARG(I)=ZQ(2,I)                                               QS049750
      FUN(I)=XQ(2,I)                                               QS049760
      GUN1(I)=YQ(2,I)                                              QS049770
510   CONTINUE                                                     QS049780
      DO 520 J=1,NZGRID                                            QS049790
      ETA(J,1)=0.0                                                 QS049800
      ZETA(J,1)=ZQ(4,1)-DELZ*(J-1.0)                               QS049810
      RQ=ZETA(J,1)                                                 QS049820
      X(J,1)=FNTRP(ARG,FUN,RQ,NETAO)                               QS049830
      Y(J,1)=FNTRP(ARG,GUN1,RQ,NETAO)                              QS049840
520   CONTINUE                                                     QS049850
      NEND=2*NZGRID-1                                              QS049860
      ISTART=NZGRID+1                                              QS049870
      DO 530 J=ISTART,NEND                                         QS049880
      IML=2*NZGRID-J                                               QS049890
      ETA(J,1)=0.0                                                 QS049900
      ZETA(J,1)=-ZETA(IML,1)                                       QS049910
      X(J,1)=X(IML,1)                                              QS049920
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      Y(J,1)=Y(IML,1)-PSAVE                                      QS049930
  530 CONTINUE                                                   QS049940
      ILIM=MUM+2                                                 QS049950
      DO 540 I=1,ILIM                                            QS049960
      ARG(I)=ZQ(1,I)                                             QS049970
      FUN(I)=XQ(1,I)                                             QS049980
      GUN1(I)=YQ(1,I)                                            QS049990
  540 CONTINUE                                                   QS050000
      DO 550 J=1,NEND                                            QS050010
      ETA(J,NEGRID)=1.0                                          QS050020
      ZETA(J,NEGRID)=ZETA(J,1)                                   QS050030
      RQ=ZETA(J,NEGRID)                                          QS050040
      X(J,NEGRID)=FNTRP(ARG,FUN,RQ,ILIM)                         QS050050
      Y(J,NEGRID)=FNTRP(ARG,GUN1,RQ,ILIM)                        QS050060
  550 CONTINUE                                                   QS050070
      DO 560 I=1,NZET4                                           QS050080
      IML=NZET4+1-I                                              QS050090
      ARG(I)=EQ(4,IML)                                           QS050100
      FUN(I)=XQ(4,IML)                                           QS050110
      GUN1(I)=YQ(4,IML)                                          QS050120
  560 CONTINUE                                                   QS050130
      DO 570 I=1,NEGRID                                          QS050140
      ETA(1,I)=(I-1.0)*DELE                                      QS050150
      ZETA(1,I)=ZQ(4,1)                                          QS050160
      RQ=ETA(1,I)                                                QS050170
      X(1,I)=FNTRP(ARG,FUN,RQ,NZET4)                             QS050180
      Y(1,I)=FNTRP(ARG,GUN1,RQ,NZET4)                            QS050190
  570 CONTINUE                                                   QS050200
      DO 580 I=1,NEGRID                                          QS050210
      ETA(NEND,I)=ETA(1,I)                                       QS050220
      ZETA(NEND,I)=-ZETA(1,I)                                    QS050230
      X(NEND,I)=X(1,I)                                           QS050240
      Y(NEND,I)=Y(1,I)                                           QS050250
  580 CONTINUE                                                   QS050260
      DO 585 I=1,NZETO                                           QS050270
      IML=NZETO+1-I                                              QS050280
      ARG(I)=EQ(3,IML)                                           QS050290
      FUN(I)=XQ(3,IML)                                           QS050300
      GUN1(I)=YQ(3,IML)                                          QS050310
  585 CONTINUE                                                   QS050320
      DO 587 I=1,NEGRID                                          QS050330
      ETA(NZGRID,I)=(I-1.0)*DELE                                 QS050340
      ZETA(NZGRID,I)=0.0                                         QS050350
      RQ=ETA(NZGRID,I)                                           QS050360
      X(NZGRID,I)=FNTRP(ARG,FUN,RQ,NZETO)                        QS050370
      Y(NZGRID,I)=FNTRP(ARG,GUN1,RQ,NZETO)                       QS050380
  587 CONTINUE                                                   QS050390
      X(1,1)=-4.0*PSAVE                                          QS050400
```

```
      X(NZGRID,1)=4.0*PSAVE
      X(NEND,1)=-4.0*PSAVE
      Y(1,1)=YQ(4,NZET4)
      Y(NZGRID,1)=YQ(3,NZETO)
      Y(NEND,1)=YQ(4,NZET4)

      L=NEGRID
      L=NEND
      L=NZGRID

C      GIVEN PERIODIC BOUNDARY AND BLADE SHAPE, SOLVE THE BOUNDARY VALUE
C      PROBLEM
C      FOR THE INTERNAL GRID POINTS.

      BIJ=2.0*(1.0/(DELE**2)+1.0/(DELZ**2))
      BIJP=1.0/(DELE**2)
      BIJM=BIJP
      BIPJ=1.0/(DELZ**2)
      BIMJ=BIPJ
      NEG2=NEGRID-1
      NZG2=NEND-1
      EPP=1.E-05
      DO 600 ITER=1,100
      ERR=0.0
      DO 610 I=2,NZG2
      DO 610 J=2,NEG2
      IF(I .EQ. NZGRID) GO TO 610
      XHOLD=X(I,J)
      YHOLD=Y(I,J)
      X(I,J)=C/BIJ*(BIPJ*X(I+1,J)+BIMJ*X(I-1,J)+BIJP*X(I,J+1)+BIJM*X(I
     *,J-1)) +(1.-C)*X(I,J)
      Y(I,J)=C/BIJ*(BIPJ*Y(I+1,J)+BIMJ*Y(I-1,J)+BIJP*Y(I,J+1)+BIJM*Y(I
     *,J-1)) +(1.-C)*Y(I,J)
      ERR=ERR+ABS(X(I,J)-XHOLD)+ABS(Y(I,J)-YHOLD)
610   CONTINUE
      IF(ITER .LT. 5) GO TO 600
      ERR=ERR/(2.0*NEG2*NZG2)
      IF(ERR .LE. EPP) GO TO 670
      KPRT=ITER/200
      IF(ITER .NE. 200*KPRT) GO TO 600
      DO 620 I=1,NEND
620   CONTINUE
600   CONTINUE



670   CONTINUE
```

```
      WRITE(6,4444) ITER,ERR
4444  FORMAT(' ITER COUNT FOR INTERNAL GRID POINTS= ',I3,' ERR= ',E15.5)
      DO 650 I=1,NEND
      DO 650 J=1,NEGRID
      ZPET(I,J)=X(I,J)+AI*Y(I,J)
650   CONTINUE


      MM=NEGRID
      NN=NEND
      K=1
      ZPET(1,1)=-2.0*CHORB+AI*YQ(4,NZET4)
      ZPET(NZGRID,1)=2.0*CHORB+AI*YQ(3,NZETO)
      ZPET(NEND,1)=-2.0*CHORB+AI*YQ(4,NZET4)
C     ZPET(1,1)=-2.*CHORX+0.
C     ZPET(NEND,1)=ZPET(1,1)
C     ZPET(NZGRID,1)=2.*CHORX+0.


      DO 675 I=1,NEND
      DO 675 J=1,NEGRID
      ZPET(I,J)=ZPET(I,J)*CEXP(-AI*STAG*PI/180.0)
      X(I,J)=REAL(ZPET(I,J))
      Y(I,J)=AIMAG(ZPET(I,J))
675   CONTINUE
      ETADF1=-DELZ
      ETADF2=-ETADF1
      ZETDF1= DELE
      ZETDF2=-ZETDF1
      ET(1)=FLOAT(NZGRID-1)*(-DELZ)
      ZET(1)=0.
      DO 4844 I1=2,NEND
4844  ET(I1)=DELZ+ET(I1-1)
      DO 4845 I1=2,NEGRID
4845  ZET(I1)=DELE+ZET(I1-1)
      NOZ=NEND
      DO 780 I=1,NEND
      DO 780 J=1,NEGRID
      ZPET(I,J)=ZPET(I,J)*CEXP(AI*STAG*PI/180.0)
780   CONTINUE
      DO 790 I=1,NEND
      ZTEMP=(ZPET(I,NEGRID)+ZPET(I+1,NEGRID))/2.0
      ZTEMQ=ZTEMP*CEXP(-AI*STAG*PI/180.0)
      XT=REAL(ZTEMP)
      YT=AIMAG(ZTEMP)
      XR=REAL(ZTEMQ)
      YR=AIMAG(ZTEMQ)
790   CONTINUE
```

```
      STAG=STAG*PI/180.
      PITCH=PSAVE
      RETURN
      END
      SUBROUTINE CHLSKY(A,C,N)
      IMPLICIT REAL*8 (A-H,O-Z)
C - CHOLESKY - SOLVES AN N BY N SYSTEM OF EQUATIONS WITH COEFFICIENT
C   -
C   MATRIX A(I,J), CONSTANT VECTOR C(I), AND SOLUTION VECTOR.
C   CHOLESKYS METHOD IS USED.  IT REQUIRES N**2 + O(N) OPERATIONS.
C
      DIMENSION A(63,63),C(63)
C
C - CALCULATION OF SOLUTION MATRIX.  NOTE BOTH THE UPPER AND LOWER
C   TRIANGULAR MATRICES ARE STORED AS REPLACEMENT VALUES IN MATRIX A.
C   ALSO THE SOLUTION VECTOR REPLACES THE CONSTANT VECTOR (C).
C

      IST = 1
      JST = 2
      DO 50 K = 1,N
C
C - CALCULATION OF LOWER TRIANGULAR MATRIX ELEMENTS
C
      DO 10 I = IST,N
      J = 0
20    J = J+1
      IF (J.GE.K) GO TO 10
      A(I,K) = A(I,K) - A(I,J)*A(J,K)
      GO TO 20
10    CONTINUE
C
C - CALCULATION OF UPPER TRIANGULAR MATRIX ELEMENTS
C
      IF (K.EQ.N) GO TO 50
      DO 40 J = JST,N
      I = 0
30    I = I+1
      IF (I.GE.K) GO TO 40
      A(K,J) = A(K,J)-A(K,I)*A(I,J)
      GO TO 30
40    A(K,J) = A(K,J)/A(K,K)
      IST = IST+1
50    JST = JST+1
C
C - CALCULATION OF CONSTANT VECTOR ELEMENTS.  ENTRY POINT FOR MULTIPLE
C   SOLUTION INVOLVING THE SAME COEFFICIENT MATRIX, BUT CHANGES IN
C   CONSTANT MATRIX.
```

```
C                                                                       QS051850
      ENTRY CHGCNT(A,C,N)                                               QS051860
      NP1 = N+1                                                         QS051870
      DO 70 K = 1,N                                                     QS051880
      I = 0                                                             QS051890
60    I = I+1                                                           QS051900
      IF (I.GE.K) GO TO 70                                              QS051910
      C(K) = C(K) - A(K,I)*C(I)                                         QS051920
      GO TO 60                                                          QS051930
70    C(K) = C(K)/A(K,K)                                                QS051940
C                                                                       QS051950
C - EVALUATION OF SOLUTION MATRIX                                        QS051960
C                                                                       QS051970
      DO 90 K = 1,N                                                     QS051980
      L = NP1-K                                                         QS051990
      M = NP1                                                           QS052000
80    M = M-1                                                           QS052010
      IF (M.LE.L) GO TO 90                                              QS052020
      C(L) = C(L)-A(L,M)*C(M)                                           QS052030
      GO TO 80                                                          QS052040
90    CONTINUE                                                          QS052050
      RETURN                                                            QS052060
      END                                                               QS052070
```

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